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OF THE

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W. H. MAW, Esq., PRESIDENT, in the Chair.

Scriven Bolton, 24 Kensington Terrace, Hyde Park, Leeds ;
Bahne Bonniksen, 16 Norfolk Street, Coventry ;
Edwin Turner Cottingham, The Limes, Thrapston ;
William George Hooper, Wiverton House, Musters Road, West Bridgford, Nottingham ;
Percy Merivale Marshall, Filey House, Livingstone Road, Scarborough ; and
Karl Pearson, M.A., LL.B., F.R.S., Professor of Applied Mathematics and Mechanics, University College, London ; and 7 Well Road, Hampstead, N.W.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Walter Sidney Adams, M.A., Solar Observatory, Mount Wilson, California, U.S.A. (proposed by G. E. Hale) ;
Ernest Percival Cotton, Surveyor General and Commissioner of Crown Lands, Lands and Survey Department, Lagos, West Africa (proposed by W. H. Walmsley) ;
Rev. Alex. C. Henderson, B.D., The Manse, Delting, Brae, Shetland, N.B. (proposed by Rev. J. Spence) ;
Rev. Frederick John Jervis-Smith, M.A., F.R.S., M.Inst.E.E., University Lecturer in Mechanics and Millard Lecturer in Engineering and Mechanics, Trinity College, Oxford (proposed by H. H. Turner) ; and
T. Hobart Pritchard, 5 Cotford Road, Thornton Heath, Surrey (proposed by T. W. Brownell).

Sixty-nine presents were announced as having been received since the last meeting, including, amongst others :—

G. Bigourdan, Les Eclipses de Soleil : instructions sommaires sur les observations que l'on peut faire pendant les éclipses, presented by the Author ; map of England showing track of total solar eclipse of 1927, presented by Rev. S. J. Johnson.

On Hansen's Coefficients for the Inequalities in the Moon's Longitude. By E. Nevill.

As I have already stated on several occasions during the last ten years, my own calculations have sufficed to confirm the accuracy of the values given by Hansen in the *Darlegung* for the coefficients of the inequalities in the expression for the Moon's longitude derived from the direct perturbing action of the Sun, the difference being seldom more than a few hundredths of a second of arc.

This statement has now been confirmed by the still more complete calculations of Professor Brown (*Monthly Notices*, vol. lxv. p. 276) ; and it follows that the theoretical expression for the disturbing action of the Sun on the normal elliptic motion of the Moon must be held to have been determined with all requisite accuracy.

The differences between the tabular and theoretical values of the coefficients are not sufficient to produce any important discrepancy between the tabular and observed places, as they will seldom much exceed a second of arc, and be in general much smaller.

Hence the existing large discordances between the tabular and observed places of the Moon must be ascribed to some different origin—to the effect of the perturbations of the planets, the figure of the Earth, or some similar cause.

This result is most important, for it clears the field.

For the sake of comparison I give the results that I have derived, reduced with values of the constants which differ but very slightly from those made use of by Newcomb in his transformation of Hansen's theoretical values. They are the results which have been adopted in my investigation of the errors of Hansen's tables now awaiting printing.

They have been compared with :

1. Hansen's theory.
2. Hansen's tables.
3. Brown's theory as brought up to Hansen's data $= B + R$.

The notation is Hansen's : the smaller terms have been generally omitted, and the values carried only to two places of decimals.

Argument.	Coefficient.	Correction to reduce to the values of Hansen's Theory.	Hansen's Tables.	Brown's Theory.
		"	"	"
g	+ 22640·15	+ ·00	+ ·50	+ ·00
$2g$	+ 769·06	+ ·00	− ·09	+ ·00
$3g$	+ 36·13	+ ·00	− ·01	− ·01
$4g$	+ 1·94	+ ·00	− ·01	+ ·00
$-3g-g'$	+ ·55	+ ·00	− ·00	+ ·00
$-2g-g'$	+ 7·67	+ ·00	− ·01	+ ·00
$-g-g'$	+ 109·88	+ ·04	+ ·07	+ ·06
$-g'$	+ 669·85	+ ·00	+ ·16	− ·10
$g-g'$	+ 148·28	− ·26*	− ·25	− ·22
$2g-g'$	+ 9·72	+ ·00	+ ·00	+ ·01
$3g-g'$	+ ·67	+ ·00	+ ·00	+ ·01
$-g-2g'$	+ 1·17	+ ·01	+ ·01	+ ·00
$-2g'$	+ 7·50	+ ·01	+ ·02	+ ·03
$g-2g'$	+ 2·58	+ ·01	− ·01	+ ·02
$2g-2g'$	+ ·19	+ ·00	+ ·00	+ ·01
$-3g'$	+ ·10	− ·02	− ·01	+ ·00
$g-3g'$	+ ·06	− ·01	+ ·00	− ·01
$+2\omega-2\omega'$	− ·22	− ·01	− ·07	− ·04
g	− 2·50	− ·04	+ ·02	− ·05
$2g$	− ·18	− ·01	− ·01	− ·01
$-g-g'$	+ ·12	+ ·06	+ ·00	+ ·06
$-g'$	+ 2·40	+ ·12*	+ 15	+ ·10
$g-g'$	− 28·25	− ·31*	− ·34	− ·29
$2g-g'$	− 24·45	+ ·00	+ ·00	− ·03
$3g-g'$	− 2·95	+ ·02	+ ·03	+ ·02
$4g-g'$	− ·29	+ ·00	+ ·00	+ ·00
$-2g-2g'$	+ ·97	− ·02	− ·02	− ·02
$-g-2g'$	+ 13·22	− ·03	− ·02	− ·03
$-2g'$	+ 211·74	− ·03	− ·05	− ·07
$g-2g'$	+ 4586·66	− ·10*	+ ·02	− ·11
$2g-2g'$	+ 2369·74	+ ·01	+ ·39	+ ·16
$3g-2g'$	+ 191·96	− ·01	− ·01	− ·01
$4g-2g'$	+ 14·39	− ·01	− ·02	+ ·00
$5g-2g'$	+ 1·06	+ ·00	+ ·00	+ ·00
$-g-3g'$	+ ·49	− ·01	− ·04	− ·01
$-3g'$	+ 8·66	+ ·00	+ ·03	− ·01
$g-3g'$	+ 206·30	+ ·16*	+ ·19	+ ·18
$2g-3g'$	+ 165·54	+ ·02	+ ·01	+ ·01
$3g-3g'$	+ 14·61	− ·01	+ ·00	+ ·01

Argument.		Coefficient.	Correction to reduce to the values of Hansen's Theory.	Hansen's Tables.	Brown's Theory.
		"	"	"	"
$4g-3g'$	+	1·18	+·00	+·01	+·00
$-4g'$	+	·28	+·00	−·14	+·02
$g-4g'$	+	7·46	−·02	−·05	−·01
$2g-4g'$	+	8·12	+·01	+·00	+·02
$3g-4g'$	+	·74	+·02	+·02	+·02
$g-5g'$	+	·25	+·01	+·00	+·00
$2g-5g'$	+	·32	+·02	+·02	+·03
$g-3g'+4\omega-4\omega'$	+	·02	+·02	+·02	+·01
$2g-3g'$	−	·51	+·15*	+·14	+·15
$3g-3g'$	−	·69	+·05	+·05	+·05
$4g-3g'$	−	·29	+·00	+·00	+·00
$g-4g'$	+	1·15	+·03	+·02	+·04
$2g-4g'$	+	30·77	+·01	+·01	+·00
$3g-4g'$	+	38·45	−·02	−·02	−·02
$4g-4g'$	+	13·94	−·04	−·04	−·04
$5g-4g'$	+	1·95	+·03	+·03	+·03
$g-5g'$	+	·07	+·00	+·00	+·03
$2g-5g'$	+	2·75	+·00	−·01	−·01
$3g-5g'$	+	4·35	+·06*	+·05	+·06
$4g-5g'$	+	1·79	+·10*	+·10	+·09
$5g-5g'$	+	·26	+·03	+·02	+·02
$2g-6g'$	+	·13	+·03	+·03	+·03
$3g-6g'$	+	·30	+·01	+·01	+·01
$4g-6g'$	+	·14	+·01	+·01	+·01
$3g-6g'+6\omega-6\omega'$	+	·28	+·01	+·02	+·01
$4g-6g'$	+	·55	+·02	+·02	+·02
$5g-6g'$	+	·37	+·03	+·02	+·02
$6g-6g'$	+	·13	+·00	+·00	+·00
$g'+2\omega$	+	·01	+·00	+·01	+·01
$g+g'$	−	·09	+·00	+·00	+·01
$2g+g'$	+	·42	+·00	+·00	+·00
$-g$	+	·06	+·01	+·00	+·00
$+2\omega$	+	1·30	−·21†	−·07	+·00
g	−	39·50	−·08†	+·23	+·04
$2g$	−	411·63	+·03	−·12	−·06
$3g$	−	45·10	−·01	+·00	−·01
$4g$	−	4·01	+·01	+·01	+·01
$5g$	−	·33	+·00	+·00	+·00

Argument.	Coefficient.	Correction to reduce to the values of Hansen's Theory.	Hansen's Tables.	Brown's Theory.
	"	"	"	"
$-g'+2\omega$	+ ·01	+ ·06	− ·02	+ ·02
$g-g'$	+ ·10	− ·02	− ·02	− ·02
$2g-g'$	− ·08	+ ·00	+ ·00	+ ·00
$3g-g'$	− ·30	+ ·00	+ ·00	+ ·00
$-g+3g'+2\omega'$	+ ·37	+ ·03	− ·03	+ ·00
$+3g'$	− 2·16	+ ·01	− ·01	+ ·00
$g+3g'$	+ ·05	− ·01	+ ·00	+ ·01
$-2g+2g'$	+ ·44	− ·01	− ·02	+ ·02
$-g+2g'$	+ 6·37	− ·01	+ ·05	+ ·01
$+2g'$	− 55·28	+ ·03	+ ·30	+ ·10
$+g+2g'$	− ·15	− ·03	+ ·00	− ·03
$+2g+2g'$	+ ·56	+ ·00	+ ·00	+ ·00
$-g+g'$	− ·08	+ ·00	+ ·00	+ ·00
$+g'$	+ 1·50	+ ·05†	+ ·00	− ·06
$2g-2g'+4\omega-2\omega'$	− ·53	− ·01	+ ·00	− ·01
$3g-2g'$	− 9·37	+ ·00	+ ·00	+ ·00
$4g-2g'$	− 5·74	+ ·00	− ·01	+ ·00
$5g-2g'$	− 1·00	+ ·01	− ·01	+ ·01
$6g-2g'$	− ·12	+ ·00	+ ·00	+ ·00
$3g-3g'$	− ·43	+ ·00	− ·04	+ ·00
$4g-3g'$	− ·38	+ ·00	+ ·00	+ ·00
$5g-3g'$	− ·07	− ·01	+ ·00	+ ·01
$g-4g'+2\omega-4\omega'$	+ ·25	− ·03	− ·01	+ ·00
$2g-4g'$	+ ·00	+ ·00	+ ·02	+ ·03
$3g-4g'$	− ·04	− ·01	+ ·02	+ ·01
$4g-4g'+6\omega-4\omega'$	− ·15	− ·02	+ ·00	...
$5g-4g'$	− ·19	− ·01	− ·01	+ ·02
$6g-4g'$	− ·18	+ ·09†	+ ·09	− ·02
$3g+4\omega$	+ ·08	+ ·00	+ ·00	+ ·00
$4g-4\omega$	+ ·42	+ ·00	+ ·00	+ ·00
$5g$	+ ·09	+ ·00	+ ·00	+ ·00
$-g+\omega-\omega'$	+ ·35	+ ·03	+ ·02	+ ·00
$+\omega-\omega'$	+ 1·18	+ ·15†	+ ·41	+ ·08
$+g$	+ 18·08	+ ·01	+ ·07	+ ·07
$2g$	+ 1·25	+ ·02	+ ·03	+ ·03
$-g-g'$	− 1·75	− ·03	− ·04	− ·01
$-g'$	− 18·73	+ ·03	− ·42	+ ·04
$g-g'$	− 125·90	+ ·47†	− ·54	+ ·15

Argument.		Coefficient.	Correction to reduce to the values of Hansen's Theory.	Hansen's Tables.	Brown's Theory.
			"	"	"
$2g - g'$	−	8·52	−·04	−·02	+·01
$3g - g'$	−	·59	+·00	+·00	−·01
$-2g'$	−	·15	−·02	+·00	−·01
$g - 2g'$	−	·59	−·01	+·00	−·03
$2g - 2g'$	−	·12	−·01	−·01	+·00
$g - 2g' + 3\omega - 3\omega'$	−	·03	−·01	−·01	−·01
$2g - 2g'$	+	·28	+·00	+·00	+·00
$3g - 2g'$	+	·15	+·00	+·00	+·00
$g - 3g'$	−	1·23	+·01	−·02	+·00
$2g - 3g'$	−	3·16	−·07*	−·06	−·07
$3g - 3g'$	+	·47	−·06*	−·06	−·07
$g - 4g'$	−	·08	+·00	−·01	+·00
$2g - 4g'$	−	·22	−·01	−·02	−·01
$3g - 4g'$	+	·08	+·02	−·01	−·01
$2g - g' + 3\omega - \omega'$	+	·02	+·00	+·00	+·00
$3g - g'$	+	·24	+·01	+·00	+·01
$4g - g'$	+	·04	+·00	+·00	+·01
$g - 3g' + \omega - 3\omega'$	−	·30	−·02	+·00	+·05
$g' + \omega + \omega'$	+	·06	+·02	+·05	−·02
$g + g'$	+	·58	−·03	−·02	+·00
g	+	·05	+·01	−·01	−·04

Differences of $\pm 0''{\cdot}01$ or even of $\pm 0''{\cdot}02$ mean little, as the greater part of their magnitude arises in the contraction from three to two places of decimals.

In seventeen cases where my own results differ sensibly from those found by Hansen from his last theoretical calculation, in eleven cases marked by an asterisk (*) Hansen's values are confirmed by Professor Brown, showing that in these instances my own approximations have not been carried sufficiently far or some combination of several terms has been overlooked ; and in six cases marked with a dagger (†) my own results are confirmed by Professor Brown.

The details of the calculation of my own results are intended to form the third volume of the work on the lunar theory carried out at the Natal Observatory. The method adopted is that developed in the *Memoirs* of the Society for 1879, only substituting numerical values for the algebraical expansion of the different integrating factors. A good deal yet remains to be done to reduce the mass to a form available for printing, as nothing has been done for the last ten years when it was put away until funds were likely to be available for printing.

Distortion in Photographic Images with the 13-inch Astrographic Object-glass of the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The measures of the reference stars of the *Eros* photographs have incidentally provided material for a determination of the optical distortion of the object-glass. The reduction of the measures was made in the same way as those for the *Astrographic Catalogue* (Greenwich *Astrographic Catalogue*, vol. i., Introduction, p. xliv), three arbitrary constants being adopted for each plate, viz. two to fix the centre and one for the orientation—the correction for scale value being obtained from the mean of all the photographs, and the corrections for differential refraction and aberration being computed. The differences between the photographic and the assumed positions of the reference stars derived from meridian observations appear as residuals between the standard coordinates computed from the assumed right ascensions and declinations and those obtained from the measures. As the same star frequently occurs on a number of plates, and may be near the centre on some and at some distance from it on others, comparison of the residuals shown at different distances from the centre may be made to determine the distortion of the field, the images within 40′ of the centre being sensibly unaffected by distortion.

For example, the star B.D. +44°, 326 occurs on photographs obtained on 1900 December 13, 15, and 16. The approximate coordinates and residuals on the several plates are given in the following table :

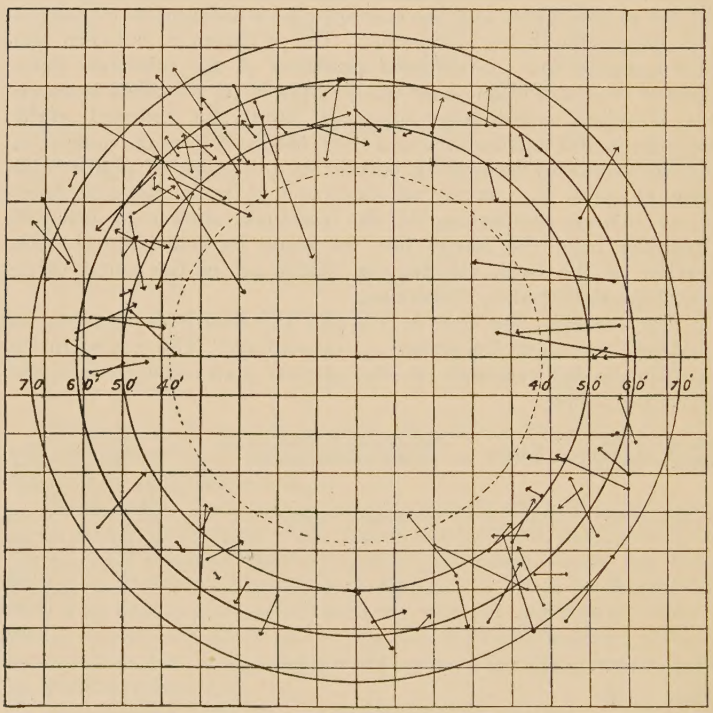
No. of Plate.	Position of Instrument.	Date.	Approximate Coordinates and Distance from Centre.			Residuals (Tab.−Obs.)	
			x.	y.	r.	Δx.	Δy.
		1900.	″	″	′	″	″
5288	E	Dec. 13	−1000	−3100	55	+·05	−·06
89	E	,,	,,	,,	,,	−·06	−·22
90	E	,,	,,	,,	,,	−·11	−·15
94	E	,,	,,	,,	,,	+·13	−·34
97	E	,,	,,	,,	,,	+·10	+·07
99	W	Dec. 15	−2400	− 200	40	+·16	−·40
5300	W	,,	,,	,,	,,	−·15	−·36
04	E	,,	,,	,,	,,	−·06	−·36
06	E	,,	,,	,,	,,	+·02	−·27
07	E	,,	,,	,,	,,	−·34	−·28
08	W	Dec. 16	−3000	+1300	55	−·13	−·42

Date.	Weight.	Mean Residuals. x.	Mean Residuals. y.
1900.		″	″
Dec. 13	5	+·02	−·14
,, 15	5	−·07	− 33
,, 16	1	− 13	−·42

Images within 40′ of the centre have been considered as free from optical distortion, and the differences between the residuals have been treated as entirely due to this cause. By subtraction the following are obtained :

x.	y.	r.	Δx.	Δy.	No. of Photos.
′	′	′	″	″	
−1000	−3100	55	−·09	−·19	5, 5
−3000	+1300	55	+·06	+·09	1, 5

The quantities Δx and Δy were tabulated for all the reference stars and plotted as shown in the diagram, and the values of Δr (the radial component) measured off.



Apparent Distortion on *Eros* Photographs.
Amount and direction of distortion indicated by the arrows. Scale $1^d = ″·2$.

The values of Δr found between different limits of distance from the centre are shown in the following tables, the number of photographs on which the results depend being given in the second and third columns, the number in the third column referring to the comparison photographs on which the images are within 40′ of the centre.

r 45′ to 50′.		r 50′ to 55′.		r 55′ to 60′.		r 60′ to 65′.	
Δr.	No. of Photos.	Δr.	No. of Photos.	Δr.	No. of Photos.	Δr.	No. of Photos.
″		″		″		″	
+·15	3, 5	+·13	5, 1	−·04	1, 2	−·47	1, 5
+·15	2, 6	+·18	3, 3	+·20	5, 5	−·42	1, 1
+·11	5, 5	−·05	2, 1	−·02	1, 5	+·26	1, 3
−·10	3, 5	−·11	5, 1	−·13	1, 10	−·29	4, 2
−·25	1, 5	−·13	2, 3	−·20	3, 6	−·30	5, 2
−·29	3, 3	−·19	1, 2	−·22	6, 4	−·01	1, 2
−·03	7, 7	+·02	5, 5	+·06	3, 11	−·43	2, 7
+·04	3, 2	+·02	5, 4	+·19	4, 10	−·06	1, 4
−·07	1, 10	−·39	5, 6	+·37	3, 4	+·28	3, 1
+·07	5, 5	+·33	1, 3	+·07	1, 3	−·72	1, 3
+·08	7, 7	−·11	5, 3	·00	3, 6	−·15	1, 7
−·09	5, 7	−·28	3, 1	+·07	1, 3	+·11	3, 4
+·10	5, 5	−·10	5, 3	+·12	6, 5	−·15	1, 1
+·19	3, 6	−·04	6, 6	−·18	4, 13	−·19	1, 1
+·06	1, 3	−·21	2, 3	·00	4, 8		
+·60	1, 1	+·19	3, 1	+·03	6, 3	r 65′ to 70′.	
−·10	5, 12	+·12	4, 1	−·44	7, 4	Δr.	No. of Photos.
−·09	1, 4	−·05	6, 15	+·13	2, 15	″	
+·02	5, 9	−·09	6, 3	+·12	4, 1	−·35	4, 13
−·17	5, 3	−·04	2, 10	+·02	3, 4	−·20	1, 1
+·11	2, 1	−·21	1, 1	+·10	1, 2	−·24	2, 4
−·28	2, 6	+·04	2, 4	+·02	1, 1	−·41	3, 3
+·07	7, 10	−·02	1, 6	−·87	1, 6	−1·02	2, 4
−·05	7, 8	+·49	1, 7	−·39	4, 3	−·31	3, 3
−·01	7, 7	−·10	3, 1	−·26	4, 3	+·24	1, 1
−·11	1, 7	+·22	4, 4	−·11	4, 1	−·32	5, 1
+·08	3, 5	−·14	2, 3	−·40	1, 3	r 70′ to 75′.	
−·16	5, 3	−·18	3, 4	−·12	3, 4	Δr.	No. of Photos.
−·07	2, 1	−·12	5, 1	+·02	1, 1	″	
+·10	2, 1			−·30	3, 4	+·11	2, 5
+·07	3, 1			−·66	1, 3	−·74	7, 4
+·15	2, 1			−·56	1, 3	+·02	4, 1
+·04	3, 1					−·12	2, 5
−·12	4, 4						
+·14	4, 4						
−·02	1, 4						
+·19	1, 1						
+·04	3, 4						

The means in the above tables were taken in two ways : (i.) the simple mean, the result for each star being considered of equal weight ; (ii.) the weighted mean, the weight being equal to the number of photographs on which the distorted images occur. The results are shown in the following table :

Limits of Distance.	Mean Distance from Centre.	No. of Stars.	Weight.	Mean Distortion. (i.)	Mean Distortion. (ii.)	Mean Discordance after Correction for Distortion.	Mean Discordance (Uncorrected).
′ ′	′			″	″	″	″
45–50	47·5	38	130	+·014	+·005	±·12	·12
50–55	52·5	29	98	−·029	−·044	·14	·15
55–60	57·5	32	93	−·106	−·083	·21	·20
60–65	61·6	14	26	−·181	−·166	·21	·27
65–75	70·0	12	36	−·262	−·354	·25	·34

The table given above shows :

(i.) At greater distances than 55′ from the centre star-images are in the mean sensibly distorted inwards.

(ii.) The amount of this distortion is subject to such variations depending on the magnitude of the star and exposure of the photograph that very little is gained by applying this mean correction. The means irrespective of sign of Table I. given in the last column of Table II. are sensibly the same as the discordances obtained after applying the mean distortion.

(iii.) The falling-off in accuracy due to photographic distortion is very marked beyond 55′ from the centre.

In the reduction of the *Eros* photographs no correction is being applied for distortion, and reference stars at greater distances than 55′ from the centre of the plate are not used except in one or two instances, where the number of stars is very small.

Magnetic Disturbances as recorded at the Royal Observatory, Greenwich, and their Association with Sun-spots. Third Paper. By E. Walter Maunder.

7. *Diurnal Inequality in Magnetic Disturbances.*

An examination of the two catalogues of magnetic disturbances contained in my first and second papers respectively (*Monthly Notices*, vol. lxv. pp. 2–34, and 538–559) shows a marked tendency in the selected times of commencement to favour certain hours of the Greenwich day. Table XIV. brings this tendency into prominence, and with it a curious difference between the catalogue in Table I. of the years 1882 to 1903 and that in Table IX. of the years 1848 to 1881.

Both catalogues agree in giving the commencement of at least

three out of every four disturbances as falling between noon and midnight, and hardly one fourth between midnight and noon. Both agree also as to a fairly even distribution of the disturbances through these morning hours—0 hours to 11 hours inclusive. But there is a striking difference between the two catalogues as to the distribution during the evening hours, 12 hours to 23 hours. For whilst Table I. gives a very sharply defined maximum at 13 hours, Table IX. rises, with a regularity which precludes the possibility of accident, to a most unmistakable maximum at 18 hours.

It is not to be supposed that this difference indicates any change in the actual disturbances themselves taking place about the years 1881 or 1882 ; it is merely a question of a systematic difference in the taking out of the times of commencement.

Disturbances may be divided into two classes according to the character of their commencement. All very great storms and not a few minor ones begin with the characteristic sharp instantaneous impulse indicated by the letter "S" in Table I. These constitute the first class, and there is no ambiguity about the times of their commencement, except in the cases of a few long-continued storms, showing more than one of such sharp movements following a period of rest.

But there may be considerable ambiguity about the time of commencement of the second class, the more numerous but usually less intense disturbances where no such sharp initial movement is shown. These begin in many ways : sometimes by rapid but slight "fluctuations," sometimes by a single "wave," sometimes by a succession of small movements of varying character and amplitude.

Here there is room for some uncertainty in fixing the time of commencement. It is not an uncertainty which has any serious effect upon the *interval* between successive disturbances, nor in any case is it sufficiently large seriously to affect the relation of disturbances "in sequence."

TABLE XIV.

Hourly Distribution of Magnetic Disturbances.

Greenwich Civil Time. h	1848 to 1881.	1882 to 1903.			1848 to 1903.		
			Commencement.				
		All.	Sharp.	Gradual.	Great.	Active.	Moderate.
0	12	5	1	4	1	6	10
1	11	3	2	1	3	5	6
2	8	6	2	4	2	7	5
3	7	10	6	4	2	8	7
4	5	5	3	2	2	5	3
5	6	5	3	2	2	5	4
6	8	8	3	5	2	6	8
7	7	2	0	2	0	3	6

Greenwich Civil Time. h	1848 to 1881.	1882 to 1903.			1848 to 1903.		
		All.	Commencement.		Great.	Active.	Moderate.
			Sharp.	Gradual.			
8	6	9	6	3	4	5	6
9	7	4	2	2	2	7	2
10	8	7	4	3	4	5	6
11	11	5	2	3	3	10	3
12	12	24	1	23	2	18	16
13	22	40	4	36	6	18	38
14	26	29	8	21	8	15	32
15	31	20	5	15	1	19	31
16	39	20	5	15	1	26	32
17	42	9	2	7	4	19	28
18	45	15	2	13	3	20	37
19	43	16	4	12	6	16	37
20	26	10	4	6	2	13	21
21	24	9	0	9	0	10	23
22	15	9	5	4	2	10	12
23	24	6	3	3	2	12	16
0–11	96	69	34	35	27	62	66
12–23	349	207	43	164	37	206	323
Total...	445	276	77	199	64	268	389

But if the point to be determined is not the *interval* between two disturbances, but the precise hour at which each commences, the problem is rendered difficult by the strongly marked tendency of minor magnetic movements to vary in character with the local time.

This tendency may be illustrated by Table XV., in which the small isolated "wave" movements of the declination magnet at Greenwich for the year 1894 February 1 to 1895 January 31 are arranged according to the civil hour of the beginning of the swing. It will be seen at once how strongly marked is the tendency for eastward waves to take place about 18 hours or 19 hours; for westerly waves to occur in the hours immediately after midnight. The movements represented in this table are those given in the "Notes" of the Greenwich volumes; the more considerable movements represented in the plates are therefore not included.

An inspection of Table XIV. shows how strongly the times of the smaller disturbances are affected by this diurnal inequality.

The "great" disturbances are distributed throughout the 24 hours with almost complete impartiality. So, too, are the disturbances which open with the characteristic sharp to-and-fro impulse. But less than one in four of the "active," hardly one in six of the "moderate," have their beginnings between midnight and noon; and those of gradual commencement show the same unequal tendency.

TABLE XV.

Hourly Distribution of Small Wave-movements, 1894–5.

Greenwich Civil Time. h	Declination.		Horizontal Force.		Greenwich Civil Time. h	Declination.		Horizontal Force.	
	Westerly.	Easterly.	Increase.	Decrease.		Westerly.	Easterly.	Increase.	Decrease.
0	14	6	13	1	12	1	1	2	1
1	12	2	7	1	13		2	3	3
2	11	2	7	1	14		3	3	2
3	10	2	4	3	15		4	3	4
4	3		2	1	16	2	9	8	8
5	4		1		17		20	9	8
6	2		1	1	18		29	11	9
7	1			1	19		21	14	3
8	2				20		19	11	5
9					21	2	16	16	4
10					22	3	18	19	2
11					23	4	8	8	

If our magnetic disturbances are excited from without, then when any large number of them are taken it is natural to expect that they will be found distributed indifferently to the local time at any one station. The "sharp" movements are, as far as we know, simultaneous over the whole earth, and hence are independent of local time. So, too, with storms of the first rank: their times of commencement are indifferent to local time. But the phases of the after-development of a disturbance are not so independent, and give clear indications of their connexion with the presentation of the observing station with respect to the Sun; or, in other words, with local time. With the less intense disturbances therefore, the phases connected with the local time are of greater relative distinctness, and the times when the phases of diurnal disturbance are most strongly marked are naturally most often taken as the times of commencement. These times are: first, about six o'clock in the evening, when the easterly "wave" in declination is most frequent; and second, shortly after noon, when a westerly movement made up of small "fluctuations" is apt to set in. In Table IX.—the catalogue of the disturbances from 1848 to 1881—the former phase had the

most effect, for the times were determined by reference to the original photographic registers, and the sheets for the days preceding and following the disturbances were examined, and the most striking change was taken as the point of commencement. In Table I.—the catalogue of the disturbances from 1882 to 1903—the times were taken from the reproductions of the registers given in the plates of the Greenwich volumes, and these in the majority of cases began with Greenwich noon; hence the fluctuations of the early afternoon more frequently caught the attention. A reference to the original registers showed that, had the times for these later years been taken out from them, the same massing of disturbances around 18 hours civil time would have been seen in the catalogue of Table I. as in that of Table IX. For, though so many of our magnetic disturbances are world-wide, and though the sharp impulse with which not a few commence occurs, so far as we know, at the same minute of absolute time the whole world over, yet these disturbances often differ much at different stations in intensity, in character, and in the absolute times at which the subordinate phases develop. So far as Greenwich, at least, is concerned, there is a strong tendency for certain well-marked phases to recur with the same hours of local time as Tables XIV. and XV. indicate; the most obvious of these "local time movements" occurring between noon and midnight, and culminating near six o'clock in the evening.

It is obvious that stream-lines from the Sun, such as the interval-relation shows us to be the exciting instruments of our magnetic disturbances, must—since they overtake the Earth in its orbit—strike it first on the sunset arc and move across the sun-lit face to the sunrise arc. Over and above any *general* effect upon the Earth's magnetism as a whole, we may therefore naturally expect that disturbances thus excited will show certain *local* peculiarities dependent upon the presentation of the several observing stations towards the Sun at the moment when the solar stream overtakes the Earth. This presentation varies with the hours of the local day and with the season of the year, and therefore some kind of a diurnal inequality, some kind of an annual inequality, might naturally be expected in the disturbances recorded at any given station. Inequalities with daily and with annual periods do exist, not only in the diurnal range, but also in the disturbances. Table XIV., given above, illustrates the diurnal inequality in disturbances at Greenwich; Table XIX., which follows later, shows that there is an evident annual inequality. Whether these two inequalities here illustrated are those which should be looked for as a consequence of the action of the solar stream-lines is a point which I wish at present to reserve.

My present purpose is to call attention to two points: *first*, that local peculiarities, both diurnal and annual, are to be expected in the record of magnetic disturbances at any given station as a consequence of the solar excitation; and *second*, that

though the local peculiarities which have been observed with these daily and yearly periods tend to blur the evidence for the "Interval-Relation," they by no means efface it, for the whole of the evidence for that relation presented in my two former papers is evidence which is still outstanding after these and possibly other effects have done their utmost to impair or conceal it. I now offer a short catalogue of disturbances observed at a distance from Greenwich as an example of the manner in which the relation still comes out, even when no precise points of the disturbances are taken to work upon.

8. *Comparison of Greenwich and Toronto Records.*

Magnetic observatories seldom publish in their results any information about magnetic disturbances, or if they give such information it is usually not in a form convenient for comparing the observations made at different stations. But a short catalogue published in 1875 by the Director of the Toronto Observatory came under my notice, and seemed very suitable for my purpose. It is found on p. 55 of a volume of *Abstracts and Results of Magnetical and Meteorological Observations at the Magnetic Observatory, Toronto, Canada, from* 1841 *to* 1871 *inclusive*, and is headed "Dates (Astronomical Time) at which unusually large Disturbances of Declination occurred at the Ordinary Observation Hours, with the Amount of Abnormal Variation of each such Disturbance. Declination, Abnormal Variation not less than 15′. The + sign indicates an Easterly Disturbance, and — a Westerly Disturbance."

In Table XVII. the second and third columns are reproduced exactly from this catalogue; the third and fourth columns contain the number of the rotation and the longitude of the Sun's centre; the last four columns are derived from Table IX., and give the Greenwich disturbances for the same nine years. The first column gives a reference number for the Toronto disturbance. When two or more succeeding observations appeared to be made during the course of the same storm, a number is only given to the first, and the longitude of the Sun's centre is calculated for the time of that observation alone.

It will be observed that this is not a list of the times of the commencements of the disturbances, but of cases when, at the ordinary times of observation—2^h, 4^h, 10^h, 12^h, 18^h, and 20^h Toronto astronomical time—the declination magnet was found to be displaced from its normal position for the day and hour by more than 15′. A comparison shows that the times given fall on the average about nine hours later in absolute time than those given in Table IX., but a diurnal inequality is distinctly brought out, the numbers for the different hours running as under :—

TABLE XVI.

Toronto Civil Time.	Disturbances of Declination.		
	Easterly.	Westerly.	Total.
h			
0	25	12	37
6	2	31	33
8	0	26	26
14	4	0	4
16	4	1	5
22	44	4	48
Total	79	74	153

Table XVIII. shows that, though this diurnal inequality is clearly brought out, and though the times given are not those of the commencements of the disturbances, nor of any specific phase, and are, further, limited to six points of the day, yet that the Interval-Relation shows itself. It will be seen also from Table XVIII. that sometimes a sequence appears in the Toronto catalogue which would have been missed in the Greenwich list, some disturbances strongly marked at Toronto being only feebly felt at Greenwich. This seems to have been the case in the greatest of all the abnormal variations at Toronto, No. 75. On the other hand the longest and most complete sequence at Greenwich—No. liii. of Table X.—comes out only imperfectly in the Toronto list. If the disturbances of the two catalogues, Greenwich and Toronto, are plotted down together in diagrammatic form, as was done in Plate I. of my first paper, the Interval-Relation comes out in a much more striking manner than could be inferred from a consideration of the disturbances registered at either observatory separately. It is not merely that the two observatories supplement each other's records, but the combination of the two catalogues emphasises the solar longitudes to which no disturbances correspond. Sequence No. liii. is seen to be of no exceptional length. It is clear, therefore, that a complete inquiry into the Interval-Relation can only be made from a comparison of the registers of several widely distributed magnetic observatories. Is it too much to ask that such observatories should publish in their annual volumes a few leading details concerning the principal disturbances observed during the year; the times when they began, ended, and attained their greatest intensity, and the degree and character of the chief movements? A simple list, too, of the times when the sharp characteristic movement was observed—which often ushers in great storms, but also occurs at other times—would be of great value.

TABLE XVII.

Comparison of Magnetic Disturbances, 1863 to 1871, as observed at Toronto and at Greenwich.

Toronto.							Greenwich.					
Ref. No.	Date Toronto Mean Time.			Amount.	No. of Rotation.	Long. of Sun's Centre.	Ref. No. Table IX.	Date G.M.T.			No. of Rotation.	Long. of Sun's Centre.
								1863.	d	h		°
							196	Jan.	8	4	123	108·1
							197		10	10	...	78·5
	1863.	d	h	′		°						
1	Jan.	12	18	− 25·8	123	44·9	198		12	3	...	56·0
2		24	12	+ 36·1	124	250·2	199		24	7	124	255·8
...		25	20	− 24·3	...	..						
							200		29	4	...	191·6
							201		31	2	...	166·4
3	Feb.	6	20	− 20·7	...	74·6	202	Feb.	6	15	...	80·2
							203		22	8	125	233·4
4		25	18	− 24·8	125	185·5	204		25	5	...	195·5
							205	Mar.	21	6	126	238·7
5	Apr.	8	10	+ 16·5	127	356·2	206	Apr.	8	5	...	1·8
							207		15	6	127	268·9
6	May	5	10	+ 27·1	128	359·5						
7	July	6	10	+ 19·1	130	259·1						
8		15	10	+ 27·4	...	140·0	208	July	15	9	130	143·5
							209	Aug.	13	10	131	119·4
							210		28	2	132	285·5
9	Sept.	9	20	− 33·8	132	114·2	211	Sept.	9	6	...	124·8
...		10	12	− 20·0	...	...						
							212		23	6	133	300·0
10	Oct.	8	10	+ 38·4	133	97·0	213	Oct.	7	8	...	114·2
11	Nov.	5	12	+ 15·9	134	86·6	214	Nov.	5	7	134	92·3
12		14	10	+ 28·4	135	329·0	215		14	1	135	336·9
13	Dec.	11	20	− 18·6	...	327·7						
								1864.				
							216	Feb.	1	6	137	13·5
							217		11	8	138	240·7
							218	Mar.	6	6	139	285·7
							219		10	3	...	234·6
	1864.											
14	Mar.	31	12	+ 20·5	140	319·9						
							220	Apr.	27	6	141	319·6
15	Apr.	29	10	+ 23·5	141	287·1						
16	May	5	12	+ 15·9	...	207·6	221	May	5	6	...	213·9
							222		25	6	142	309·3

Toronto.							Greenwich.					
Ref. No.	Date Toronto Mean Time.			Amount.	No. of Rotation.	Long. of Sun's Centre.	Ref. No. Table IX.	Date. G.M.T.			No. of Rotation.	Long. of Sun's Centre.
	1864.	d	h	′		°		1864.	d	h		°
17	June	7	12	+ 34·2	142	131·1	223	June	7	4	...	138·4
18		8	18	− 23·6	...	114·5						
							224		22	16	143	293·2
19	July	19	10	− 35·9	144	296·3	225	July	18	15	144	309·7
							226	Aug.	13	7	145	330·2
20	Aug.	24	10	− 26·9	145	180·3						
							227	Sept.	16	19	146	234·5
							228		20	10	...	186·6
21	Sept.	23	4	+ 16·8	146	147·4	229		22	7	...	161·9
22	Oct.	12	20	− 22·1	147	247·9	230	Oct.	13	5	147	245·9
...		14	12	− 23·8	...	...						
...		14	20	− 15·6	...	...						
							231		19	3	...	167·9
							232	Nov.	11	2	148	225·1
23	Nov.	15	10	+ 23·8	148	165·1	233		15	1	...	173·0
24	Dec.	7	10	+ 16·1	149	235·2						
25		11	20	− 16·7	...	176·9	234	Dec.	12	2	149	176·6
							235		15	1	...	137·6
							236		23	3	...	31·1
								1865.				
							237	Jan.	11	5	150	139·8
							238		16	4	...	74·5
							239		25	2	151	317·1
							240	Feb.	15	6	...	38·4
							241		16	23	...	15·9
							242		21	2	152	321·6
							243	Mar.	15	7	...	29·0
	1865.											
26	Mar.	20	12	− 17·2	153	317·4	244		20	3	153	325·3
27	Apr.	15	10	+ 22·7	154	335·5	245	Apr.	16	6	154	327·4
							246	May	13	7	155	330·0
28	June	5	12	+ 17·9	155	20·0						
29		9	10	+ 24·6	156	328·2	247	June	9	11	156	330·6
30		15	10	− 21·5	...	248·8						
31	July	18	4	+ 15·9	157	175·3						
32	Aug.	2	2	+ 22·0	158	338·0	248	Aug.	2	6	158	338·7
...		2	18	+ 28·9	...	...						
...		2	20	− 63·4	...	...						

Toronto. Ref. No.	Date Toronto Mean Time.			Amount.	No. of Rotation.	Long. of Sun's Centre.	Greenwich. Ref. No. Table IX.	Date. G.M.T.			No. of Rotation.	Long. of Sun's Centre.
	1865.	d	h	′		°		1865.	d	h		°
...	Aug.	3	2	+ 33·2	...	...						
...		4	18	− 38·8	...	...						
							249	Aug.	10	6	...	232·9
33		11	18	− 21·5	...	210·2						
							250		14	7	...	179·5
34	Sept	20	12	− 16·2	159	35·1						
							251	Oct.	4	17	160	220·5
35	Oct.	12	20	− 17·5	160	110·4						
36		13	18	− 26·6	...	98·3						
...		13	20	− 31·9	...	...						
37		18	20	− 15·5	...	31·3	252		19	0	...	32·0
							253		26	3	161	298·0
38		30	18	− 22·2	161	234·1	254		29	23	...	247·5
...		30	20	− 22·0	...	...						
...		31	12	+ 15·4	...	...						
...		31	18	− 42·8	...	...						
...		31	20	− 20·5	...	...						
							255	Nov.	3	5	...	191·4
	1866.											
39	Jan.	10	10	+ 20·4	163	9·7						
40		27	10	+ 15·9	164	145·9						
								1866.				
41	Feb.	7	10	+ 29·2	...	1·1	256	Feb.	6	3	164	21·0
42		20	12	− 54·7	165	188·8	257		20	13	165	191·1
							258		23	6	...	155·5
43	Mar.	7	10	+ 15·4	166	352·3	259	Mar.	6	8	...	9·5
44		18	18	− 20·2	...	202·9	260		18	7	166	211·9
45	Apr.	3	18	− 15·0	167	351·9						
46		17	10	+ 17·4	...	171·5						
47	May	12	12	+ 17·4	168	200·0						
48	June	15	18	− 15·4	169	106·8						
49	Aug.	9	10	+ 15·5	171	103·5						
50		23	10	+ 15·5	172	278·4	261	Aug.	23	4	172	284·6
51		29	18	− 20·2	...	194·7						
							262	Sept.	9	5	...	59·5
52	Sept.	17	18	− 27·5	173	303·8						
53	Oct.	3	10	+ 25·7	...	97·1	263	Oct.	4	4	173	90·1
54		5	18	− 15·9	...	66·3	264		6	3	...	64·3

Toronto.							Greenwich.					
Ref. No.	Date Toronto Mean Time.			Amount.	No. of Rotation.	Long. of Sun's Centre.	Ref. No. Table IX.	Date G.M.T.			No. of Rotation.	Long. of Sun's Centre.
	1866.	d	h	′		°		1866.	d	h		°
55	Oct.	7	18	− 18·9	...	39·9						
56		9	12	+ 22·7	...	16·8						
57		10	18	− 33·6	...	0·3						
58		11	18	− 20·2	174	347·1	265	Oct.	12	6	174	343·5
59		13	10	+ 29·3	...	325·1						
60		18	10	+ 27·0	...	259·2						
61		30	12	+ 16·2	...	99·8						
62	Nov.	1	10	+ 37·4	...	74·6						
63		25	20	− 18·2	175	112·7	266	Nov.	26	3	175	111·7
								1867.				
							267	Feb.	8	6	178	215·5
							268		13	6	...	149·6
							269	Mar.	6	5	179	233·5
							270		10	6	...	180·3
	1867.											
							271	May	28	7	182	216·4
64	June	1	10	+ 18·8	182	158·9	272	June	1	11	...	161·3
65	Aug.	31	10	+ 16·6	185	35·2						
							273	Sept.	7	1	186	310·6
66	Sept.	17	10	+ 17·0	186	170·7						
67		21	12	− 15·7	...	116·8						
68		25	12	+ 16·1	...	64·0	274		25	4	...	71·3
69	Oct.	2	12	+ 15·0	187	331·6	275	Oct.	2	7	187	337·3
70		29	18	− 15·6	188	332·2						
								1868.				
							276	Feb.	20	5	192	280·4
							277	Mar.	19	15	193	266·0
							278		30	9	...	124·2
	1868.											
71	Apr.	1	12	+ 37·4	193	93·3	279	Apr.	1	10	...	97·3
...		1	20	− 21·2	...	...						
72		18	12	+ 16·5	194	228·9	280		18	11	194	232·3
							281		27	6	...	116·2
							282		29	5	...	90·3
73	May	20	10	+ 15·8	195	166·9						
74		23	12	+ 22·7	...	126·1						
75	June	10	10	+131·3	196	249·0						
76		29	12	+ 19·8	197	356·4	283	June	29	12	197	359·4
77	July	10	10	+ 17·4	...	212·0	284	July	10	2	...	219·3
...		10	12	− 37·0	...	...						

Ref. No.	Toronto. Date Toronto Mean Time.			Amount.	No. of Rotation.	Long. of Sun's Centre.	Ref. No. Table IX.	Greenwich. Date G.M.T.			No. of Rotation.	Long. of Sun's Centre.
	1866.	d	h	′		°		1868.	d	h		°
78	Aug.	4	10	+ 20·4	198	241·2	285	July	14	13	...	160·3
							286	Aug.	30	6	199	262·7
79	Sept.	15	12	− 20·9	199	45·2	287	Sept.	15	13	...	47·6
...		15	18	− 41·7	...	...						
...		15	20	− 17·7	...	...						
80		26	10	+ 44·4	200	261·1	288		27	5	200	253·6
...		26	12	+ 21·9	...	...						
81		30	12	− 69·9	...	207·2	289		30	6	...	213·5
...		30	18	− 28·2	...	...						
							290	Oct.	19	4	201	323·9
82	Oct.	22	12	+ 42·8	201	277·0	291		22	3	...	284·9
...		22	18	− 40·1	...	...						
83		23	18	− 33·2	...	260·5	292		24	3	...	258·5
...		25	18	− 18·8	...	...						
...		25	20	− 16·8	...	...						
84	Nov.	19	10	+ 24·4	202	268·9	293	Nov.	19	4	202	275·1
	1869.							1869.				
85	Jan.	19	20	− 15·2	204	179·9	294	Jan.	20	12	204	174·0
86	Feb.	3	10	+ 20·7	205	346·9	295	Feb.	2	11	...	3·4
87		23	10	+ 33·0	...	84·5						
							296	Mar.	9	7	206	264·6
							297		18	1	..	149·3
							298	Apr.	2	5	207	309·3
88	Apr.	5	12	− 22·8	207	262·9						
...		6	4	+ 21·8	...	...						
							299		8	5	...	230·1
89		15	2	+ 20·1	...	136·4	300		14	23	...	141·0
90	May	7	10	+ 18·8	208	201·4						
...		8	12	+ 16·3	...	...						
91		13	2	+ 31·3	...	126·4	301	May	13	2	208	129·3
...		13	4	+ 24·1	...	...						
							302		30	18	209	255·6
							303	June	6	14	...	165·2
92	June	15	18	− 16·3	209	41·0						
93		24	4	− 23·6	210	289·7						
							304		29	7	210	224·6
							305	July	3	10	...	169·9
							306		18	9	211	332·1

Toronto.						Greenwich.					
Ref. No.	Date Toronto Mean Time.			Amount.	No. of Rotation.	Long. of Sun's Centre.	Ref. No. Table. IX.	Date G.M.T.			No. of Rotation.	Long. of Sun's Centre.
	1869.	d	h	′		°		1869.	d	h		°
94	Aug.	6	10	+ 19·9	211	77·3	307	Aug.	6	8	...	81·3
95		15	18	− 22·4	212	313·9						
							308		20	10	212	255·1
96		24	10	+ 33·5	...	199·3	309		24	5	...	205·0
							310	Sept.	2	9	...	83·9
							311		5	7	...	45·4
							312		9	11	213	350·4
							313		11	9	...	325·1
							314		13	11	...	297·5
97	Sept.	27	18	− 16·3	213	106·0	315		27	6	...	115·5
							316	Oct.	5	22	...	1·1
							317		25	1	214	108·9
98	Dec.	13	20	− 18·7	216	179·6						
							318	1870. Jan.	2	14	217	272·4
99	1870. Jan.	8	10	+ 15·8	217	192·6						
100		26	12	+ 21·8	218	314·5						
							319		29	10	218	279·0
101	Feb.	1	12	+ 20·2	...	235·5	320		31	23	...	245·6
							321	Feb.	11	7	. .	109·5
							322		22	9	219	323·6
							323	Mar.	21	12	220	326·2
102	Mar.	30	10	+ 17·6	220	205·6						
103	Apr.	4	18	− 16·7	...	135·3	324	Apr.	4	18	...	138·2
							325		11	20	...	44·7
							326		15	12	221	356·3
							327		21	4	...	281·4
							328	May	14	15	222	331·4
							329		19	23	...	260·9
							330	June	12	5	223	313·2
104	June	14	10	+ 17·3	223	281·0						
							331		16	18	...	253·1
105	Aug.	2	18	− 23·5	225	348·2						
106		19	10	+ 36·5	...	127·8	332	Aug.	19	11	225	130·2
							333	Sept.	3	4	226	295·9
							334		7	6	...	242·0
107	Sept.	23	18	− 20·3	226	21·2	335		23	15	...	25·8
							336	Oct.	1	3	227	286·8
							337		14	4	...	114·7

Ref. No.	Toronto. Date Toronto Mean Time.			Amount.	No. of Rotation.	Long. of Sun's Centre.	Ref. No. Table IX	Greenwich. Date G.M.T.			No. of Rotation.	Long. of Sun's Centre.
	1870.	d	h	′		°		1870.	d	h		°
108	Oct.	23	18	+ 15·5	228	345·4	338	Oct.	23	22	228	346·1
...		24	12	− 22·8	...	...						
...		24	20	− 21·6	...	...						
109	Nov.	8	10	+ 23·0	...	138·8	339	Nov.	7	19	...	150·0
...		8	18	− 16·2	...							
110		18	20	− 22·7	...	1·5	340		19	3	...	0·7
111	Dec.	15	20	− 17·5	229	5·7	341	Dec.	15	16	229	10·8
...		16	20	− 17·6	...	...						
							342	1871. Jan.	4	5	230	113·4
							343		12	22	231	358·7
112	1871. Feb.	11	12	+ 16·7	232	326·3	344	Feb.	10	11	232	342·9
							345		26	4	...	136·1
							346	Mar.	1	6	...	95·4
							347		22	8	233	177·6
113	Mar.	26	20	− 15·7	233	115·3	348		27	2	...	115·0
							349	Apr.	1	8	...	45·7
114	Apr.	4	10	+ 16·9	...	2·1						
							350		9	5	234	301·8
							351		13	9	...	246·8
115		17	10	− 15·5	234	190·5	352		17	7	...	195·1
116		23	18	− 24·9	...	106·8						
117		27	20	− 20·2	...	52·9	353		28	1	...	53·0
...		28	20	− 18·5	...	...						
118	May	24	12	+ 15·8	235	60·3						
119		26	10	+ 19·0	...	34·9						
120	June	17	12	− 16·7	236	102·7	354	June	17	12	236	105·6
121	July	3	12	+ 15·0	237	250·8						
122		21	12	+ 15·7	...	12·7	355	July	21	13	237	15·0
							356	Aug.	6	1	238	170·0
123	Aug.	12	10	+ 23·1	238	82·8						
							357		21	9	239	327·3
							358		24	8	...	288·2
							359	Sept.	7	8	...	103·3
							360	Oct.	14	5	241	336·6
							361	Nov.	1	6	...	98·7
							362		9	7	242	352·7
							363		19	19	...	214·2

TABLE XVIII.

Sequences of the Toronto Disturbances.

Ref. No.	No. of Rotation.	Long.	Ref. No.	No. of Rotation.	Long.	Ref. No.	No. of Rotation.	Long.
		°			°			°
5	126	356·2	39*	164	369·7	80	200	261·1
6*	127	359·5	41	165	361·1	83	201	260·5
9	132	114·2	43	166	352·3	84	202	268·9
10	133	97·0	45*	167	351·9	89	207	136·4
11	134	86·6	48*	169	106·8	91	208	126·4
12	135	329·0	...	170	...	98*	216	179·6
13*	136	327·7	49*	171	103·5	99*	217	192·6
23	148	165·1	...	172	...	110	228	1·5
25	149	176·9	53	173	97·1	111	229	5·7
26	153	317·4	61*	174	99·8	113	233	115·3
27	154	335·5	63	175	112·7	116*	234	106·8
...	155	...†	54*	173	66·3	...	235	...
29	156	328·2	62*	174	74·6	120	236	102·7
...	157	...	69	186	331·6	117	234	52·9
32	158	338·0	70*	187	332·2	118*	235	60·3
34*	159	35·1	75*	196	249·0			
37	160	31·3	...	197	...			
			78*	198	241·2			

9. *The Annual Inequality in Magnetic Disturbances.*

I am indebted to Mr. W. Ellis, not only for the list of disturbances which I utilised in my second paper, but for a complete magnetic calendar, extending from 1848 to 1902, in which every day was classified as a day of "great," "active," "moderate," or "minor" disturbances or of "none." Mr. Ellis has used the first fifty of these fifty-five years in his paper appearing in the *Monthly Notices* for March, vol. lxv. p. 520. I may perhaps be permitted to give the figures for the entire fifty-five years in a slightly different form. I have taken the sums of the numbers of disturbances for fifteen-day periods, so arranged that the dates when the apparent centre of the Sun's disc has the least and greatest latitudes and the dates of the terrestrial equinoxes and solstices fall respectively in the middle of one or other of these periods. Five days have therefore been struck out of the year as well as February 29. It will be seen that

* Not in the Greenwich catalogue of disturbances, given in Table IX.

† This gap is filled by disturbance No. 246 of Table IX.

the figures bear out Mr. Ellis's statement that "the spring maximum appears on the whole to fall somewhat before the equinox, and the autumn maximum somewhat after the equinox." It also appears that the summer minimum in like manner falls before the solstice, and the winter minimum decidedly after. The summer minimum is very sharply marked, and coincides with the period when the Sun's equator is on the centre of the disc, and the direction of rotation makes the greatest angle with the ecliptic. The table as a whole suggests that this strongly marked annual inequality is not due to a single cause alone, but to a combination of two or more, inasmuch as the curve is not symmetrical about either the equinoxes or the dates when the Sun's equator is on the centre of the disc. It will be necessary to obtain similar figures from observatories having seasons differing markedly from those at Greenwich, and especially from observatories in the southern hemisphere, before a satisfactory interpretation can be placed upon the peculiarities shown by this annual inequality.

TABLE XIX.

Annual Distribution of Magnetic Disturbances.

From.	To.	Great.	Active.	Moderate.	Total.	
Dec. 30	Jan. 13	0	8	124	132	
Jan. 14	„ 28	0	19	178	197	
„ 29	Feb. 12	5	11	194	210	
Feb. 13	„ 27	8	30	197	235	
„ 28	Mar. 14	3	14	191	208	Hel. lat. of Earth $-7°{\cdot}2$
Mar. 15	„ 29	3	15	199	217	Spring equinox
„ 30	Apr. 13	3	18	197	218	
Apr. 14	„ 28	4	18	149	171	
„ 29	May 13	2	8	162	170	
May 15	„ 29	2	8	125	135	
„ 30	June 13	0	9	99	108	Hel. lat. of Earth 0°
June 14	„ 28	1	8	113	122	Summer solstice
„ 30	July 14	4	13	129	146	
July 15	„ 29	2	7	135	144	
„ 31	Aug. 14	8	17	133	158	
Aug. 16	„ 30	3	5	142	150	
„ 31	Sept. 14	7	16	181	204	Hel. lat. of Earth $+7°$
Sept. 16	„ 30	3	10	195	208	Autumn equinox
Oct. 1	Oct. 15	5	18	181	204	
„ 16	„ 30	4	17	199	220	
„ 31	Nov. 14	3	15	165	183	
Nov. 15	„ 29	5	9	156	170	
„ 30	Dec. 14	1	7	145	153	Hel. lat. of Earth 0°
Dec. 15	„ 29	1	7	141	149	Winter solstice

Determination of Longitude on the Planet Jupiter.

By G. W. Hough.

In the *Monthly Notices*, vol. lxiv. pp. 824–834, I published an article on longitude determinations on the planet *Jupiter*.

It would appear from a paper by Mr. A. S. Williams in *Monthly Notices*, vol. lxv. pp. 167–181, on the same subject that I failed to make clear some points in the discussion. Some further explanation may, therefore, be desirable.

The eye-estimate method has been used by many distinguished astronomers in the past in determining the rotation period of *Jupiter* and *Saturn*, and in common with everybody I imagined that it was a fairly reliable method. I had very little faith in Schmidt's variable error, and also supposed there was a *real* personal equation between different observers. The comparison of eye-estimates with the micrometer measures, however, has shown such grave errors that astronomers ought clearly to understand that a precision observation cannot be made by this method.

In meridian observations the transit of a star is observed over a group of fixed wires, from five to fifteen in number. Suppose all the wires were removed and the transit observed over an imaginary wire bisecting the field, the latter being analogous to that employed in eye-estimates. How would the two methods compare in point of accuracy in right ascension work?

The observations of the Barnard White Spot on *Saturn* in 1903, the only conspicuous spot on the disc, showed that experienced observers differed nearly twenty minutes on the same night, not once, but repeatedly. I think astronomers would not regard such as precision observations. I have already shown that a micrometer used for a fraction of the time required to secure such crude estimates would furnish observations of precision such as are demanded in other directions. If, therefore, anything I can say will induce observers who have micrometers to use them when we discover another suitable spot for determining the rotation of *Saturn* my time will not be entirely wasted.

In my previous paper I compared the micrometer results with a previously computed ephemeris by Marth to show that there was no variable or cumulative error.

As all the conclusions arrived at are based on the assumption that micrometer work is subject to accidental error only, some further explanation on this point may be desirable.

In the determination of longitude the central meridian of the disc is not directly used. The measures are referred to the limbs of the planet, and every measure for longitude is virtually a measure of the equatorial diameter, the spot or marking serving

as an intermediate step. In fact, the constants for the size of the disc were determined from such observations.

As the size of the disc from these differential measures is in harmony with direct measures it is obvious that there was no variable or cumulative error. When objects are observed at a considerable distance from the central meridian the accidental error, or the time of passage over the central meridian, may be materially increased owing to errors in the adopted constants for reduction—viz. the size of the disc, latitude, and length of the object.

If measures were always made near the central meridian I have good grounds for thinking that the mean accidental error would conform to theory—viz. one minute of rotation time.

In order to ascertain the mean personal equation and variable error all the observations used in the discussion were compared with an ephemeris derived from the micrometer measures.

For convenience in some cases the Marth-Crommelin ephemeris was corrected to conform to the true rotation-period; then both the micrometer and eye-estimates were compared, as in the example given for 1887. The residual errors, therefore, in all cases depend on the rotation-period derived from the micrometer measures.

In the eye-estimate method it seems to me there are two sources of error of vital importance.

First, personal equation.

Second, variable error, first pointed out by Schmidt.

Personal Equation.

What does personal equation indicate in eye-estimate observations? If the personal equation amounts to six minutes it means that the observer divided the disc into two *unequal parts*; that his central meridian, which he thought bisected the disc, was 1″ on one side, or one-fortieth of the diameter of the disc in error.

The range in the mean personal equation for different years (*Monthly Notices*, vol. lxiv. p. 831) is about eight minutes, which means that whenever the personal equation is changed a new central meridian is chosen. Schmidt found, from eye-estimates alone, a range of nine minutes in the personal equation for different observers. Now if the personal equation varies over such wide limits for the same observer, or for different observers, it means that the disc is not bisected by this method, and precision observations are not made. Hence, also, we may conclude that the range in personal equation is a correct measure of the amount of error in eye-estimates. It has also been shown that the personal equation is not the same for different spots observed on the same night, nor for the same spot at different oppositions.

Variable Personal Equation.

But the most serious error is the "variable personal equation," which is introduced when observations extend over a considerable interval of time. I think the term "variable personal equation" has been misunderstood; the designation "cumulative error" is preferable.

During an opposition spots or markings may be observed for 200 days or more. If, then, at the beginning of the series the micrometer and the eye-estimate are in agreement, and at the end of the series there is a difference of ten minutes more or less, and this difference varied substantially with the time, such difference has been designated as "variable personal equation" or cumulative error. It is not to be confounded with accidental error or constant error. In all the sets of observations which I compared with the micrometer, in which this error was apparent, with one exception, the difference between the micrometer and the observer increased or decreased with the time.

Variable personal equation, then, means that the observations are not referred to the same central meridian, but are gradually shifted to one side.

In this discussion nineteen sets of observations, made by five different persons, were compared with the micrometer, and in fifteen sets the cumulative error was well defined. That it may clearly be seen what effect "variable personal equation" has on the rotation period, I have determined it for the values given in *Monthly Notices*, vol. lxiv. p. 829.

			Time interval in Days.	Variable personal equation. min.	Error on rotation-period. sec.
Barnard	1891	Red Spot	122	5	1·0
,,		Long Red	85	0	0·0
,,		Small Black (a)	92	15	4·0
,,		,, (b)	85	7	2·1
Gledhill	1898	Black	144	10	1·7
Williams	1900	Red Spot	113	6	1·3

For the above six sets of observations only one, Barnard, Long Red, was free from "variable personal equation," and hence gave the correct rotation-period.

The "variable personal equation" or cumulative error may be shown to exist independently of the micrometer observations by simply comparing the rotation periods given by different observers for the same spot at the same opposition.

Schmidt's observations on the Red Spot (*Ast. Nach.* 2410) have been repeatedly quoted as a specimen of good eye-estimate work. The comparison with the micrometer measures may be of interest.

I have reduced the observations made between 1880 August 3

and 1881 March 20, a time interval of 229 days, with a variable increasing rotation-period, and compared them with the micrometer observations covering the same interval, with the following results :—

Mean personal equation	$-3^{m}\cdot04$ min. (99 obs.)
Variable personal equation ...	3
Mean O—E	$\pm2^{m}\cdot65$
Mean actual error	$\pm4^{m}\cdot05$

Schmidt found for a uniform rotation period $O-E\pm3^{m}\cdot0$.

The four observations made in 1879 were not used, but were reduced separately. When these are included the variable personal equation is about 6 min.

Motion in Longitude.

The observations of the past twenty-five years have shown that the motion of the spots and markings seen on the planet *Jupiter* is smooth, never abrupt, as has been imagined by some observers. The rotation-period may be regarded as constant for a short time interval, sometimes for the whole opposition ; but in some cases the variation is so great that the observations can only be satisfied by assuming a uniformly decreasing or increasing period.

If observations could be made with greater precision I imagine a variable rotation-period would be apparent in all cases. As the labour required to compute an ephemeris for a variable period is considerable, it is only used when the observations made during an opposition cannot be fairly satisfied with a uniform period. At mean distance 1″ represents 2300 miles, and hence a spot 1″ in diameter represents about 4,000,000 square miles.

The objects that are observed are usually many millions of miles in area, and presumably have mass. We should not expect any abrupt change in direction or rate of motion in a moving mass.

My observations of a White Spot made in 1881 have been quoted a number of times in proof of the abrupt displacement of a spot on the disc of the planet. I find three observations, October 8, 18, 20, and again three others, November 21, 24, 30, which show abnormal residuals (O—E) about 10 min. greater than the mean of the residuals for the whole opposition of 252 days. As such irregularities are not found in any other set of measures, we should not be warranted for an isolated case in assuming irregular motion, even if there was no way to account for it. But the explanation is simple. This spot, which was observed for a number of years, appeared for a short time in 1881 as a long rift in the equatorial belt, its general appearance being an oblong spot. The apparent displacement was simply

due to the use of a different reference point in making the measures. When the spot appeared as a long rift the preceding end was used, otherwise the middle of the spot.

When the rotation-period changes a number of seconds during an opposition one might naturally infer irregular motion if the observations are compared with an ephemeris based on a uniform period.

Many cases of alleged irregular motion may possibly be explained on this hypothesis.

An example of irregular motion may be found in *Ast. Nach.* 3354.

A spot observed for 205 days showed residuals $+12^m$ at the beginning and end of the series, and -3^m near the middle. When, however, the observations were compared with an ephemeris based on a uniformly increasing period they were well satisfied, and gave a mean residual $(O-E)+2^m{\cdot}0$.

Subsequent to 1879, the observations of the Red Spot covering three successive oppositions were fairly represented by assuming a uniformly increasing rotation-period. An examination of the residuals, however, indicated that the initial rotation-period was not quite correct, or that a third term was required fully to satisfy the observations.

In general, whenever there is a marked difference in the magnitude of the residuals at the ends and middle of a series it indicates a variable rotation-period.

The position in regard to eye-estimates may be summarised as follows :—

(1) The actual error of an observation is about four or five minutes on the average.

(2) The range of personal equation for different observers may reach nine minutes (Schmidt).

(3) The range of personal equation for the same observer in different years may reach eight minutes.

(4) The range in personal equation in a set of observations extending over a long time interval may exceed ten minutes.

(5) There is no *fixed* personal equation. Vide *Monthly Notices*, vol. lxiv. pp. 829–831. The term simply means the average "mean" error as referred to the true central meridian of the disc. The fictitious central meridian chosen for any group seems to be accidental, since for different spots observed on the same night the central meridian is different. To sum up the whole matter, we may say that for a space of $2''$ on the centre of the disc an observer may choose a fictitious central meridian thinking it is correct.

(6) All observers usually introduce an error depending on the time, which I have designated "variable personal equation" or cumulative error. This error is so peculiar that it is worthy of serious study. Such an error is not found in any kind of observations in the astronomy of precision. It appears, however, to be common to all observers in eye-estimates. The nature of

this error will be apparent by reference to the table of longitude given by Mr. Williams in *Monthly Notices* (Red Spot, 1887), vol. lxv. p. 175. At this time the rotation-period was practically stationary, and a constant longitude was maintained when the observations were referred to Marth's ephemeris.

Schmidt thought the variable error depended on the hour-angle, which *indirectly* depends on the time.

How does this peculiar error originate? A possible explanation is that in some way subsequent observations are influenced by preceding ones. When the rotation-period conforms very closely to a previously prepared ephemeris, as has been the case for the Red Spot, the presupposed time has a very important bearing on the observations made.

For some years the Red Spot was for a large portion of the time invisible, and its position could only be determined by the hollow in the belt; an object not well adapted for an observation of precision. We find, however, eye-estimates giving an average mean residual $O - E = \pm 1{\cdot}0^{m} = 0''{\cdot}2$. Such a degree of precision is seldom reached with the micrometer in the observation of well-defined spots, and is far beyond anything possible for the micrometer in the observation of the hollow.

The eye-estimate method for ascertaining the rotation time of a planet is simple and direct, and will continue to furnish observations of value. When the time interval is long, viz. between two oppositions, the errors I have investigated, accidental, personal equation, and cumulative, will have but little effect on the mean rotation-period derived.

It would be a curious anomaly, however, in astronomical development if there could be no improvement on a method devised more than two centuries ago, when modern instruments of precision were unknown.

Not very long ago, before equatorial mountings and driving clocks were in common use, the ring micrometer was pretty generally used for fixing the place of a comet. At the present day, however, I think few astronomers would make use of it except as a last resort.

The modern micrometer enables the observer to measure by repetition spaces smaller than can be seen with the telescope.

The principles involved in measurement are the same, whether the instrument is used for ascertaining the distance of two stars, or the distance of markings on a planetary disc. It strikes me, therefore, as a self-evident proposition that one could bisect a planetary disc with greater precision by the help of a micrometer than without one.

The Equatorial and Polar Diameters of Jupiter as measured with the Greenwich Transit-Circle, 1880–1901. By A. M. W. Downing, D.Sc., F.R.S.

In meridian transit observations the diameter of a planet may be defined as the perpendicular distance between the verticals which are tangents to the first and second limbs of the planet. This may be called the horizontal diameter at meridian passage. In the same way the vertical diameter at meridian passage is the perpendicular distance between the horizontal tangents to the north and south limbs. In the case of *Jupiter* the horizontal and vertical diameters are not generally the same respectively as the equatorial and polar diameters owing to the inclination of the planet's axis to the circle of declination.

Let P = the position-angle of the planet's axis

$$c = \sqrt{1-e^2} = \frac{b}{a} = \frac{\text{polar diameter}}{\text{equatorial diameter}}$$

$$\cot P' = \frac{\cot P}{c}, \text{ and } \tan P'' = \frac{\tan P}{c}$$

then, with sufficient accuracy in the case of *Jupiter*,

$$\text{hor. diam.} = \text{equat. diam.} \times \frac{\cos P}{\cos P'}$$

and

$$\text{vert. diam.} = \text{polar diam.} \times \frac{\cos P}{\cos P''}$$

Also let the true diameter = tabular diam. $(1+y)$, and let z be the correction to the adopted value of $\frac{b}{a}$ or c; then the equations of condition furnished by the meridian observations of diameters are:

(1) From the transit observations

$$\text{equat. diam.} \times \frac{\cos P}{\cos P'} \times y + \text{equat. diam.} \times \sin P \,.\, \sin P' \times z$$
$$= \text{observed correction to tabular horizontal diameter.}$$

(2) From the Z.D. observations

$$\text{polar diam.} \times \frac{\cos P}{\cos P''} \times y - \text{polar diam.} \times \sin P \,.\, \sin P'' \times z$$
$$= \text{observed correction to tabular vertical diameter.}$$

The variation of its coefficient is not sufficiently great to enable us to determine z satisfactorily in this way, and it seems better to adopt the value of c corresponding to the compression

of the disc of *Jupiter* deduced from the motion of the apsides of the orbit of the fifth satellite, viz. $c = \cdot 9355$, and put $z = 0$ in the equations of condition. The observations discussed in this paper have accordingly been reduced with this value of c. The adopted value of the equatorial diameter is $37''\cdot765$ at distance 5·2. The corresponding value of the polar diameter is $35''\cdot330$. The observations included in the following table are taken from the *Greenwich Observations* for the different years, and are restricted to observations made between 15 hours and 9 hours of mean time, so as to be representative of each opposition, and free from complications arising from phase, difference of brightness of background of sky, &c. The subscript figures in the fifth and sixth columns indicate the number of observations included in each mean result.

It will be noted that the observations of horizontal and vertical diameters are quite independent of each other, and are made by quite different methods ; also that the former alone are used to determine the equatorial, and the latter alone the polar diameter.

Mean Date.	Position-angle of Axis.	Tabular Diameters.		Observed Corrections to Diameters.	
		Horizontal.	Vertical.	Horizontal.	Vertical.
	°	″	″	″	″
1880 Oct. 9	336	49·17	47·06	$+1\cdot90_{24}$	$+2\cdot21_{23}$
1881 Nov. 11	345	48·77	46·07	$+1\cdot27_{28}$	$+2\cdot15_{28}$
1882 Dec. 19	359	47·49	44·42	$+1\cdot52_{20}$	$+2\cdot33_{19}$
1884 Feb. 8	13	45·07	42·44	$+1\cdot12_{19}$	$+1\cdot89_{20}$
1885 Mar. 7	23	43·84	41·83	$+1\cdot72_{28}$	$+2\cdot29_{28}$
1886 Apr. 4	25	43·32	41·54	$+1\cdot71_{24}$	$+2\cdot21_{24}$
1887 Apr. 27	22	43·84	41·78	$+1\cdot56_{24}$	$+1\cdot89_{24}$
1888 May 23	12	45·03	42·37	$+0\cdot82_{27}$	$+1\cdot98_{26}$
1889 July 3	358	46·51	43·51	$+0\cdot69_{22}$	$+2\cdot31_{22}$
1890 Aug. 9	344	47·84	45·23	$+1\cdot51_{26}$	$+2\cdot23_{26}$
1891 Sept. 30	336	47·83	45·78	$+1\cdot41_{10}$	$+1\cdot97_{9}$
1892 Oct. 14	336	49·16	46·99	$+0\cdot72_{24}$	$+1\cdot99_{24}$
1893 Nov. 27	346	48·40	45·65	$+0\cdot39_{27}$	$+1\cdot73_{27}$
1894 Dec. 31	1	47·06	44·03	$+0\cdot70_{29}$	$+1\cdot72_{29}$
1896 Feb. 13	15	44·79	42·25	$+0\cdot08_{15}$	$+1\cdot02_{15}$
1897 Mar. 12	23	43·65	41·71	$+0\cdot51_{21}$	$+1\cdot77_{21}$
1898 Apr. 8	25	43·33	41·53	$+0\cdot21_{27}$	$+1\cdot60_{27}$
1899 May 5	21	43·90	41·76	$+0\cdot88_{25}$	$+1\cdot36_{26}$
1900 May 30	10	45·25	42·51	$-0\cdot19_{22}$	$+1\cdot14_{23}$
1901 July 13	356	46·62	43·63	$+0\cdot38_{31}$	$+1\cdot40_{31}$

Combining the observations of horizontal diameter and giving equal weights to the mean results obtained for each opposition, we have

$$y = +\cdot0205 \pm \cdot0020$$

Hence the correction to the adopted value of the equatorial diameter at distance 5·2 is

$$+''\cdot774 \pm ''\cdot075$$

and the resulting value of the equatorial diameter is $38''\cdot54$.

Treating the observations of vertical diameter in the same way, we find

$$y = +\cdot0426 \pm \cdot0013$$

The correction to the adopted value of the polar diameter at distance 5·2 is

$$+1''\cdot505 \pm ''\cdot046$$

and the resulting value of the polar diameter is $36''\cdot84$.

An inspection of columns 5 and 6 of the table, however, shows that there is an apparent progressive change in the values of the observed horizontal and vertical diameters, probably due to changes in the staff of observers during the interval covered by the observations here discussed, with corresponding changes in the mean personal equation as applying to these observations.

Perhaps the most conspicuous change occurs in 1892–3; and on this account it has been considered advisable to divide the series of observations into two parts, the first extending from 1880 to 1892, and the second extending from 1893 to 1901.

Treating these partial results exactly as before, we find from the observations of horizontal diameter, 1880–1892, that the correction to the adopted value of the equatorial diameter is

$$+1''\cdot080 \pm ''\cdot067$$

and from the observations of horizontal diameter, 1893–1901, that the correction is

$$+''\cdot308 \pm ''\cdot068$$

The values of the equatorial diameter from these two series of observations are therefore

from 1880–1892	$38''\cdot84$
1893–1901	$38''\cdot07$

Similarly the observations of vertical diameter give the corrections to the adopted value of the polar diameter

from 1880–1892	$+1''\cdot700 \pm ''\cdot029$
1893–1901	$+1''\cdot209 \pm ''\cdot054$

with the corresponding values of polar diameter

from 1880–1892	...	...	...	... 37″·03
1893–1901	...	...	...	... 36·54

The results of this discussion exhibited in a tabular form are as follows :

Included Oppositions.	Equatorial Diameter.	Polar Diameter.
1880–1892	38″·84	37″·03
1893–1901	38·07	36·54
1880–1901	38·54	36·84

Report on Observations of Jupiter for 1903–4.
By Major P. B. Molesworth, R.E.

Part I. Preliminary.

Place.—Trincomali, Ceylon. Longitude east, $5^h\ 24^m\ 55^s{\cdot}6$; latitude north, 8° 33′ 24″·2. Observatory ninety-one feet above mean sea level.

Telescope.—Calver silver on glass Newtonian ; $12\frac{3}{4}$-inch aperture ; ninety-two inches focus, equatorially mounted with driving clock. The eyepieces generally employed were a Huyghenian of 230 and a Steinheil monocentric of 270.

Nomenclature.—The nomenclature I have adopted has been in use here for several years, but differs slightly from the one generally used. A diagram is given on p. 700, showing the identification of each portion of the planet. In addition to the name, a letter is allotted to each zone and belt for identification, and these are qualified by the symbols N = North, S = South, C = centre.

Scope of the Observations.—These were begun on 1903 April 21, and continued before dawn till 1903 July 30. They were continued in the evening from 1903 August 18 to 1904 February 23. They thus cover an inclusive period of 310 days, on ninety-five of which I was absent from Trincomali ; so that 215 nights were available. One hundred and forty-one of these (65·6 per cent.) were utilised, and the planet observed for central meridian transits for a total period of 287 hours ; an average of two hours four minutes per working night. Five thousand six hundred and fifty-one C.M. transits were taken, an average of nearly twenty an hour. Eight sets of measures were also made for latitude.

Colour estimations of the different belts were made on ninety-six nights. Satellite phenomena were observed on sixty-

eight nights, and careful satellite comparisons made on ninety-nine nights.

Measures.—Made with a bifilar position micrometer by Calver. Generally used with a Barlow lens, giving a screw value of 2·500. Powers 150 without the "Barlow," and 205 and 280 with it. They were generally made in daylight on account of the unsatisfactory illumination of the micrometer. Results are given in a separate table (Table II.).

Method of Observation.—The method of observation employed was that suggested by Stanley Williams in his *Zenographical Fragments*, except that in no case was any longitude worked out till the whole of the observations for the night were completed and booked. This was done to avoid any bias.

Publication of Results.—The publication of the results has been greatly delayed by ill-health, absence in England, and pressure of other work.

Part II. Disc Observations.

General description of the features noted in the various zones and belts from south to north.

(*AA*). *S. Polar Region.*—Generally a very faint brownish grey slightly striated under the best conditions of definition. The N. edge is slightly darker than the rest, and contains some very indefinite streaks. The rotation period of these is very uncertain.

(*A*) *S.S. Zone.*—Generally the faintest of the zones, but here and there containing brighter spots. Two of these were very well observed in λ262° and 38°, and were unusually brilliant objects for this latitude. Their deduced periods were $9^h\ 55^m\ 04^s{\cdot}77$ and $9^h\ 55^m\ 05^s{\cdot}94$ respectively, showing that they were involved in the same current as the material of the S. Temperate Belt (B). This is, I think, the first reliable determination of the period of white spots in this latitude.

(*B*) *S. Temperate Belt.*—Very faint grey; abnormally faint this year to my eye, containing some fairly dark streaks, the ends of which are rather diffuse. The mean period $9^h\ 55^m\ 06^s{\cdot}35$ is, I think, reliable. Five fairly well marked spots, however, between λ146° and 272° showed a considerably slower average period ($9^h\ 55^m\ 12^s{\cdot}25$). This is my first observation of spots with an abnormal period in this latitude.

(*C*) *S. Temperate Zone.*—As a rule not very bright, but containing some brilliant spots. Some of these, as Denning has recently pointed out (*Observatory*, 1904 September, page 345), possess a very considerable degree of permanence. These two spots have been well observed independently here. I have combined Denning's published results with my own, and the agreement is very close indeed. The average period for the zone is $9^h\ 55^m\ 19^s{\cdot}03$, rather slower than in previous years but, I think, perfectly reliable.

(*D*) *S. Tropical Belt.*—The darkest and most distinct of the minor belts; decided slate grey with sometimes a faint tinge of blue. It contains some very dark streaks, generally broad and knotted, and sometimes double, but more rarely double this year than usual. The average period ($9^h\ 55^m\ 18^s{\cdot}45$) is much the same as that of the S. Temperate Zone. It varies little from year to year and may be taken as reliable.

The Red Spot.—Practically unchanged in recent years. The breadth of the bay remaining fairly constant throughout the observations. The S. Equatorial Belt remains widely double and rather faint for some distance preceding the bay. The preceding shoulder is generally very faint and slightly rounded, the following shoulder very dark and pointed. A curved wisp is generally seen to join the latter with the S. Tropical Belt a short distance preceding it. On rare occasions a very faint similar wisp has been noted from the preceding shoulder, completing the oval of the Red Spot Bay. The bay is shallow but symmetrical. The Red Spot is very faint, like a faint grey stain with a slight tinge of brown under the best conditions, when the whole outline can just be made out. The ringed appearance is not so prominent as in recent years. Once or twice a very faint diffuse horizontal streak was seen crossing the spot in a line between the shoulders, but not extending the full width of the bay. The following end of the spot is slightly darker than the rest. The period for the first part of the apparition was rather more rapid than usual ($9^h\ 55^m\ 39^s{\cdot}55$), but about 1903 August 18 it slowed down to $9^h\ 55^m\ 42^s{\cdot}30$. The mean period was $9^h\ 55^m\ 41^s{\cdot}19$.

Great S. Tropical Dark Area.—One of the most striking features of the apparition, preceded and followed by two very brilliant white spots. The motion of the centre of the area was fairly uniform with a mean period of $9^h\ 55^m\ 21^s{\cdot}83$, but the length of the shade increased from about 29° of longitude on 1903 April 25 to nearly 50° on 1903 July 29. After this it remained fairly constant till near the end of the observations, when it again appeared to increase. The first increase of length seems to have been due to a retardation of the following end, while the second was due to an acceleration of the preceding end. Under good definition it presented a very curious appearance, being made up of numerous smoky wisps, springing from knots in the S. edge of S. Equatorial Belt. There were several darker condensations in it, and a dull white patch near its centre. The average period of the preceding end was $9^h\ 55^m\ 19^s{\cdot}43$, and of the following end $9^h\ 55^m\ 24^s{\cdot}23$, giving an average period for the centre of $9^h\ 55^m\ 21^s{\cdot}83$. It was nearing conjunction with the Red Spot when the observations ended.

(*E*) *Other Spots in S. Tropical Zone and S. Edge of S. Equatorial Belt* (Fs).—The S. Tropical Zone was generally bright milky white, not much inferior to the Equatorial Zone. It is crossed by several faint wisps. The spots in this zone appear to

have been considerably retarded in period compared with previous years. The average being $9^h\ 55^m\ 48^s{\cdot}47$.

(*F*) *S. Equatorial Belt.*—Much the most prominent of the belts, dark and distinct throughout, but showing a decided change of tint. Early in the observations it was a warm bluish purple ; warmest just following the Red Spot Bay, and bluest in the darker parts of the N. edge. This gradually changed to a brownish purple in August, the brown tint growing more decided as time went on. The *S. edge* was very dark and clean-cut, showing the same slight tendency to the formation of shallow white bays that I have noticed in previous years. The *centre* of the belt was nearly always rifted, the rift (especially in June) having sometimes a decided yellow tinge. The period of the white spots in it was found to be $9^h\ 51^m\ 27^s{\cdot}19$ this year, showing a progressive acceleration in period of about five seconds per annum when compared with the results for 1901 and 1902–3.

The *N. edge* is more regular than the S. edge, and is much knotted and disturbed. The motion of the dark projecting knots is not uniform, and both these and the white spots in S. edge of Equatorial Zone sharing their motion are very hard to follow, correct identification being very difficult. The deduced average period ($9^h\ 50^m\ 22^s{\cdot}72$) agrees well with my results for previous years, though these differ somewhat from those obtained by Denning and Phillips.

(*GK*) *Equatorial Zone.*—Generally very white with no trace of yellow, the brighter spots being an almost phosphorescent white. After July the brightness of the *S. edge* (G) faded considerably and became slightly shaded (the motion of this is dealt with under S. Equatorial Belt). The *N. edge* of the zone (K) was very bright throughout, always the brightest part of the disc. The brightness was remarkably uniform, and its regularity was shared by the S. edge of N. Equatorial Belt.

This region is always subject to great variations, probably cyclical, the markings being sometimes as frequent and well marked as those of the S. edge of Equatorial Zone, while at other times they completely disappear. I cannot say whether this is due to an actual cessation of activity in the spots themselves or to the interposition of some obscuring medium between our eye and the strata in which the spots occur. It appears to vary in some way with the breadth and distinctness of the N. Equatorial Belt.

(*L*) *N. Equatorial Belt.*—Its appearance in 1903–4 was most peculiar. A faint orange band was visible throughout in its position, on the *S. edge* of which lay a very narrow dark uniform purple band, containing practically no darker knots or condensations. The tint of this S. streak grew gradually warmer and browner towards the end of the apparition. Along the *N. edge* of the faint orange band was a very faint streak, continuous on the finest nights, but generally barely traceable. Here and there in this streak were short intensely dark portions, sharp and well

defined, but fading later in the apparition. Their period ($9^h\ 55^m\ 29^s{\cdot}90$) agrees well with previous years, but as usual there are traces of abnormally rapid period in a few spots.

(*M*) *N. Tropical Zone.*—Always whitest along its N. edge, where it was sometimes very bright ; but the general tint was brownish yellow, browner and yellower to S. A few diffuse white spots were seen early in the apparition in the northern part of the zone, but faded very much as time went on. Their period is remarkably uniform, and is identical with that of the short dark streaks in N. edge of N. Equatorial Belt, with which they are obviously connected.

(*MM*) *N. Tropical Belt.*—A decided bluish-grey belt having at times a peculiar, almost mauve, tinge. Some of the streaks in it are certainly double. It joins the S. edge of a very faint grey shade which extends to the N. pole. The motion of the markings in it, as in recent years, was very irregular. The mean period ($9^h\ 56^m\ 01^s{\cdot}94$) is very slow, but agrees well with the figures obtained in 1899 and 1900. The period in different years appears to depend on the varying latitude of the belt.

(*NN*) *N. Temperate Zone.*—More variable in brightness than any of the other zones. The brighter patches being vague and nebulous, with the exception of two fairly distinct spots in $\lambda 343°$ and 359°. The average period ($9^h\ 55^m\ 56^s{\cdot}11$) agrees well with previous results and appears reliable.

(*N*) *N. Temperate Belt.*—Faint bluish, generally greyer in tint than N. Tropical Belt. The spots in it give an average period of $9^h\ 55^m\ 41^s{\cdot}05$, but their motion is very irregular. The measures show a considerable displacement in latitude to the N. late in the apparition, which may account for this irregularity.

(*P*) *N.N. Zone.*—Faint and nebulous, but fairly uniform. The periods obtained for this zone in different years do not agree, and cannot be regarded as reliable.

(*Q*) *N. Polar Region.*—Generally slightly striated, with a faint bluish tinge, the S. edge being rather the darker. The mean period for spots in it is $9^h\ 55^m\ 21^s{\cdot}49$, agreeing with that obtained in 1900, but differing considerably from that for 1901. Just inside the darker border of the polar regions is a very faint zone (R), and a very faint diffuse belt (S) further N. No results could be deduced from the scattered observations of spots in these latitudes.

General Tint of Planet.—The general tint in 1903–4 was unusually white, with hardly any trace of yellow. Even with the naked eye the planet seemed a paler yellow than usual.

Relative Brightness of Zones.—The relative brightness of the various zones was noted each night, the brightest zone being numbered 1 and the others in order. A rough measure of the relative brightness has been obtained by adding all the "points"

together and dividing by the number of observations. The results are as follows :—

K.	N. edge of Equatorial Zone	1·02
G.	S. „ „	2·10
E.	S. Tropical Zone	2·88
M*n*.	N. edge of N. Tropical Zone	3·48
NN.	N. Temperate Zone (very variable) ...	4 66
C.	S. Temperate Zone	5·25
P.	N.N. Zone	6·37
A.	S.S. Zone	8·00

Measures.—Six sets of measures were made in 1903 May and three in December. The results in each case are reduced to distance from the centre at mean distance of *Jupiter* (5·20). The means of each group are then reduced to apparent latitude and corrected for the tilt of axis. In the reduction no account has been taken of polar compression, the formula employed being $\sin \phi = d/r$ where d = distance from centre and r = polar radius of *Jupiter*.

The result of a careful eye estimate of the latitude of the belts is also given, and the mean latitudes worked out at the foot of the Table (Table 2).

The results call for no remark, except as regards the progressive increase in latitude of the N. Temperate Belt.

Part III. Satellites.

Careful observations were made with a view of determining the relative brightness, albedo, colour, and variability of the four larger satellites. The convention adopted was to number the satellites each night in order of brightness on a rough diagram, with the addition of the symbols + and − (+ signifying that the satellite in question was very much brighter than the next in order—only very slightly brighter).

Relative Brightness.—A measure of this was obtained by adding up the total points for each satellite and dividing by the number of observations. The average relative brightness is as follows :

iii. = 1·00 i. = 2·09 ii. = 2·75 iv. = 3·93

Size.—On 1903 May 12 I made a careful comparison of the relative diameters of the discs with power 370. Taking that of i. as unity, I made them

i. = 1·0 ii. = 0·8 iii. = 1·4 iv. = 1·25-1·30

This agrees fairly with Barnard's measures (*Monthly Notices*, vol. lviii. p. 217)

i. = 1″·048 ii. = 0″·874 iii. = 1″·521 iv. = 1″·430

Albedo.—ii. has a peculiar sheen and almost sparkles, with evidently a very high albedo. I never remember a case of a dark transit of this satellite.

i. has a soft steady light, but is decidedly less reflective than the centre of *Jupiter*, generally grey in mid-transit.

iii. shines with a very soft, equable light, like i., but its albedo is decidedly lower; as it is grey for the greater part of its transit, even in high latitudes, and very dark at mid-transit.

The albedo of iv. is very low indeed, and its surface seems slightly less reflective than the limb of *Jupiter*. It appears grey directly after transit ingress, and is almost black at mid-transit.

Colour.—The average colours to my eye are:—i. very pale yellow, with sometimes a faint rosy tinge; ii. more decided yellow than i.; iii. very pale primrose yellow paler even than i.; iv. bluish or purplish when faintest, greyish white when brightest.

Variability.—Very difficult to estimate. iv. and ii. appear to have the greatest range; i. only very slightly variable; iii. remarkably uniform.

Effect of glare, &c.—iv. and ii. also appeared more affected by twilight and the glare of the planet, and also by haze and cloud, than the other two (a curious result, considering their utter dissimilarity in size, albedo, and colour).

To sum up, if we use the same convention I have adopted for the satellite comparisons, the relative values come out as follows:—

General brightness: iii. (1+); i. (2−); ii. (3); iv. (4).

Albedo: ii. (1+); i. (2−); iii. (3+); iv. (4).

Size: iii. (1); iv. (2+); i. (3); ii. (4).

Colour: iii. palest yellow; i. pale yellow; ii. yellowest; iv. bluish.

Variability: iv. (1); ii. (2+); i. (3−); iii. (4).

Affected by glare, &c.: iv. (1); ii. (2+); i. (3); iii. (4).

An earlier comparison of mine is given in *B.A.A.J.* (ix. 432).

Apparent Elongation of i.—The apparent elongation of i. in transit near ingress and egress was repeatedly noticed. The phenomenon is most marked at ingress. It is certainly due to the higher albedo of the equatorial portion of the satellite disc (*Mem. B.A.A.* vii., iv. 99).

Eclipses of ii.—The somewhat rare phenomenon of an eclipse of ii. just clear of occultation was seen on three occasions in 1903. On June 6 the observed interval between Ec.R. and Oc.D. was $2^m\ 55^s$ against $1^m\ 06^s$ predicted in *N.A.* On December 1 the observed interval between Oc.R. and Ec.D. was $4^m\ 58^s$ against $1^m\ 37^s$ predicted, and on December 8, $6^m\ 05^s$ against $3^m\ 29^s$ predicted; so that the observed times in every case were considerably in excess of the predicted times.

Webb (*Celestial Objects*, i. 180) speaks of only four instances being on record. This is surely a mistake, as I think I have myself witnessed eight or ten cases.

Markings on iii.—Markings were seen on the disc of iii. during transit on several occasions. If the satellite is carefully watched just as it appears to turn grey, the equatorial markings can be distinctly seen, if the conditions are good, with a power of 400 or 450.

Distortion of Shadows near Quadrature.—The distortion of the shadows at ingress and egress near quadrature was well seen on several occasions. In poor seeing the effect of the E.–W. elongation is to make the shadow appear larger and darker, while the reversed conditions make it seem very small and faint. In good air, however, the elongation can be distinctly seen, but hardly seems to attain the magnitude demanded by theory.

Part IV. General Remarks.

Cyclical Variation in Period.—If the spots in any zone are plotted on a diagram in which the verticals give dates, and the horizontal longitudes, even the most distinct and best observed ones will be found to deviate considerably from the straight line which represents their mean motion. Part of this deviation is certainly due to errors in observation, but not all. If the O—C residuals are worked out for each observation, they will be found to have a gradually increasing + value for some time up to a maximum, after which they will gradually decrease to a negative maximum, returning again to the zero line. This is particularly striking in the cases where I have incorporated some of Mr. Denning's results (*Obs.* 1904 September) for S. temperate spots with my own. I have worked out the residuals for both observers, and Mr. Denning's observations almost invariably confirm mine, while his residuals have the same sign and approximately the same magnitude as those of my observations made about the same time. These are in many cases far too large to be due to errors of observation.

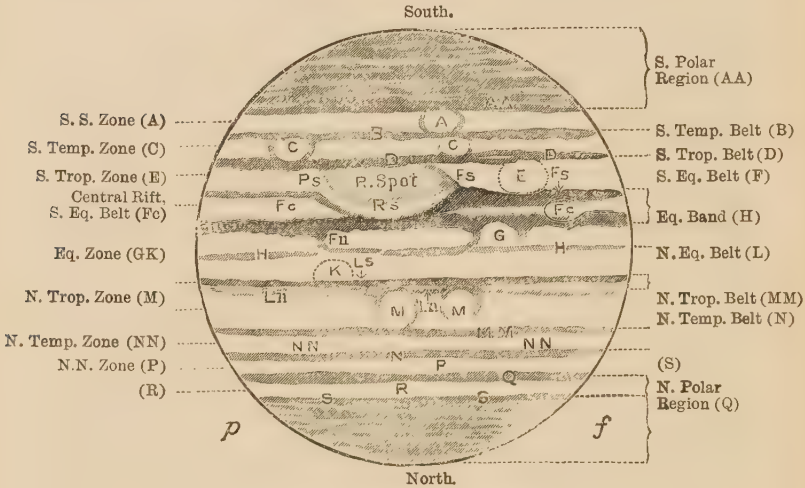
In the hope of obtaining some clue to the causes governing this variation, I worked out the O—C residuals for the whole of my observations of system ii. spots. This has entailed an enormous amount of work and delayed the publication of results, but has led to practically no result.

There is an unmistakable cyclical "swing" in period, of variable magnitude and duration ; but I cannot determine its cause, or the laws which govern its action. It may possibly be due to tidal action of the four larger satellites, the apparent irregularity depending on the varying configurations of the four. I should be very glad if some one, with more leisure and mathematical ability than I have, would thoroughly investigate the question. My observations would, I believe, give sufficient data to work on, and I should be delighted to place them at his disposal. A few years ago, from the movements of the two shoulders of the Red Spot Bay, I was led to strongly suspect a period of ± 90 days between maximum variations, but I have been unable to confirm this since.

Possible Extension of the Atmosphere of Jupiter.—I have carefully studied the behaviour of the satellites this year when close to *Jupiter*. The glare of the planet undoubtedly affects the brightness of the satellite considerably, and the different satellites are affected in different degrees. Estimations of this sort are particularly liable to error, but the observations this year confirm those of previous years, and tend to show that the satellites are very much fainter near occultation than when in similar positions with respect to *Jupiter* near transit, often losing fully half their light. The difference is most striking with ii. Near transit this satellite is very brilliant, but near occultation seems often hardly brighter than the limb. The evidence is rather conflicting, but seems to point to the existence of an invisible atmosphere round the planet, which extends some distance from the apparent limb. The idea is not new, and the explanation seems rational when we consider the probable high temperature of the planet.

Visibility of the Red Spot Bay.—For several years I have made a practice of noting the visibility of the Red Spot bay at varying distances from the C.M. when coming on and passing off. The observations agree very well, and tend to show that the following shoulder is more easily visible coming on than passing off, while the reverse is the case with the preceding shoulder. Coming on, the following shoulder is visible under favourable conditions when 70° of longitude from the C.M. ; while passing off it has already begun to be very nebulous and indistinct before it reaches 60° from the C.M. The preceding shoulder, on the other hand, is very hard to see coming on until less than 50° from the C.M. ; while passing off it can sometimes be traced almost to the limb, and clearly to 65° or more of longitude from C.M. The shade of the Red Spot itself is more apparent when coming on and going off than when it is actually on the central meridian. This latter phenomenon is possibly due to the surface of the spot consisting of slightly roughened cloud masses, which introduce slight shadow effects when obliquely lighted, thereby increasing the apparent darkness of the spot. When near the C.M. the illumination would be

nearly vertical, and the shadow effects would disappear. I append a diagram showing the nomenclature adopted and two tables



NOMENCLATURE DIAGRAM.

TABLE I.

Rotation Periods in Different Zones for the Six Years 1898 *to* 1903–4.

Belt or Zone.	No. of Spots.	Average No. of Rotations.	Average No. of Observations. 1898.	Period. h m s	No. of Spots.	Average No. of Rotations.	Average No. of Observations. 1899.	Period. h m s	No. of Spots.	Average No. of Rotations.	Average No. of Observations. 1900.	Period. h m s
(AA) ...	...	...	...	...	...	...	...	...	8	220	7·4	9 55 32·24
(A) ...	...	...	...	...	...	...	...	...	8	433	7·7	9 55 22·21
(B) ...	4	116	4·2	9 55 5·91	3	105	3·3	9 55 5·60	21	508	14·5	9 55 6·60
(C) ...	3	128	6·0	9 55 14·63	5	109	3·4	9 55 15·87	22	498	15·4	9 55 16·54
(D) ...	3	70	2·6	9 55 15·17	15	167	5·5	9 55 16·01	24	510	17·8	9 55 17·22
(E) ... (Fs) ...	...	...	...	...	1	206	12·0	9 55 41·89	12	560	26·9	9 55 41·92
R. Spot	3	257	18·0	9 55 40·63	3	262	15·0	9 55 42·01	3	693	42·6	9 55 41·53
G. S. T.	...	...	...	...	...	...	...	...	...	...	...	...
(FC) ...	...	...	...	...	5	137	3·8	9 54 44·56?	13	440	8·1	9 51 37·30
(Fn) ... (G) ...	...	...	...	...	42	194	6·3	9 50 23·06	46	585	23·8	9 50 22·36
(H) ...	...	...	...	...	8	159	3·4	9 50 29·94	13	505	14·6	9 50 25·23

"G. S. T." = Great South Tropical Dark Area.

Belt or one.	No. of Spots.	Average No. of Rotations.	Average No. of Observations. 1898.	Period. h m s	No. of Spots.	Average No. of Rotations.	Average No. of Observations. 1899.	Period. h m s	No. of Spots.	Average No. of Rotations.	Average No. of Observations. 1900.	Period. h m s
(K) ... (s) ...	...	...	...	...	...	...	...	...	22	614	15·0	9 50 29·04
(c) ...	...	...	...	...	10	183	5·0	9 55 35·01	10	562	25·1	9 55 29·18
(n) ...	6	196	11·1	9 55 26·67	21	171	6·7	9 55 30·83	20	612	35·0	9 55 30·47
(I) ...	...	...	...	...	...	...	...	...	6	646	39·5	9 55 21·46†
(IM)	...	...	...	...	6	123	4·5	9 56 6·41	13	496	17·1	9 56 0·21
(N)	...	...	...	...	...	...	...	...	5	307	7·2	9 55 58·97
(') ...	2	123	7·0	9 55 50·65	5	173	4·4	9 56 17·54?	14	430	11·0	9 55 37·92
(.) ...	...	...	...	...	...	...	...	...	5	284	5·8	9 55 35·21
(.) ...	...	...	...	...	...	...	...	...	4	517	12·7	9 55 19·12
		1901.				1902–3.				1903–4.		
(A) ...	4	421	6·2	9 55 22·75	...	...	...	...	4	432	52·0	9 55 14·24
(.) ...	5	380	7·2	9 55 19·88	1	567	4	9 55 36·95?	2	593	16·0	9 55 5·16
(:) ...	21	525	11·2	9 55 6·14	3	635	7·7	9 55 4·01	9	569	16·0	9 55 6·35
									5	649	16·6	9 55 12·25†
(.) ...	22	526	12·3	9 55 18·26	2	142	6·5	9 55 18·84	12	686	30·4	9 55 19·03
(') ...	25	514	12·0	9 55 17·76	7	564	7·3	9 55 17·88	17	658	27·6	9 55 18·45
(.) ... (s) ...	...	...	...	...	...	...	...	...	8	357	17·3	9 55 48·47
(or Spot	3	633	29·0	9 55 40·63	3	752	20·7	9 55 39·70	3	714	44·7	9 55 41·19
(T S. T.	1	611	29·0	9 55 19·33	4	689	18·0	9 55 14·42	4	716	49·5	9 55 21·83
					4*	540	....	9 55 21·15				
(c) ...	20	492	9·6	9 51 32·29	...	...	...	...	16	599	10·4	9 51 27·19
(n) (') ...	56	539	15·3	9 50 25·89	18	673	9·5	9 50 25·90	42	685	25·0	9 50 22·72
(') ...	9	464	7·0	9 50 27·98	...	...	...	...	18	552	7·6	9 50 24·89
(.) ... (s) ...	44	519	8·3	9 50 25·29	3	700	12·0	9 50 41·97	2	597	6·0	9 50 49·06?
(n) ...	28	532	11·2	9 55 29·72	13	597	9·3	9 55 26·72	13	570	27·0	9 55 29·90
(IM)	9	527	6·7	9 55 39·29?	2	434	7·0	9 55 50·76	11	495	13·2	9 56 1·54
(N)	2	570	7·0	9 55 56·27	...	...	...	...	18	545	9·7	9 55 55 11
(') ...	16	478	9·4	9 55 42·88	1	666	9·0	9 55 50 55	19	618	18·2	9 55 41·05
(.) ...	13	477	7·7	9 55 37·80	...	...	...	...	12	478	7·9	9 55 39·93
(.) ...	21	458	8·4	9 55 39·66	...	...	...	...	11	411	11·6	9 55 21·49

"G. S. T." = Great South Tropical Dark Area.

* Intermediate period, 1903 January–April. † Abnormal.

Table II.

Measures 1903–4.

Date. 1903.	Approx. G.M.T.	Power.	Definition.	Approx. Longitude (System II.).	Distance from Centre at Mean Distance 5·20. Centre S. Tropical Belt (D).	S. Edge of S. Equatorial Belt (Fs).	N. Edge of S. Equatorial Belt (Fn).	S. Edge of N. Equatorial Belt (Ls).	N. Edge of N. Equatorial Belt (Ln).	Centre. N. Tropical Belt (MM).	Centre. N. Temperate Belt (N).	Polar Diameter. Observed (O).	Calculated (C).	O–C.	Reduced to Distance 5·20.	O–C.
				°	″	″	″	″	″	″	″	″	″	″	″	″
May 12	12·47	280	good to sharp	320	− 7·660	− 4·758	−2·310	+1·862	+ 3·698	+ 7·186	...	...	...	...	...	...
19	12·40	280	sharp	285	− 7·826	− 6·056*	−2·158	+2·009	+ 2·946	+ 7·160	+ 9·689	...	...	...	...	...
21	12·27	280	sharp, falling off	217	− 7·964	− 5·159	−2·759	+1·778	+ 3·570	+ 6·823	+ 9·482	36·02	35·66	+0·35	36·311	+0·366
25	12·40	280	,,	108	− 8·620	− 5·090	−2·520	+2·040	+ 3·770†	+ 7·530	...	36·36	36·06	+0·30	36·241	+0·296
26	12·33	280	sharp	253	− 8·674	− 5·419	−1·990	+2·094	+ 3·552	+ 7·210	+10·111	36·47	36·22	+0·25	36·246	+0·301
27	12 40	205	sharp, falling off	48	...	− 4·730	−2·192	+1·702	+ 3·529	+ 7·262	...	36·71	36·39	+0·39	36·378	+0·433
May Observations (micrometer).			Means		− 8·149	− 4·934	−2·320	+1·914	+ 3·459	+ 7·195	+ 9·761			Mean ...	36·294	+0·349
			Apparent latitude	...	S. 26°97	S. 15°93	S. 7°42	N. 6°12	N. 11°10	N. 23°60	N. 32°90					
			Correction to centre (B)		+ 1·52	+ 1·52	+1·52	+1·52	+ 1·52	+ 1·52	+ 1·52					
			True latitude (ϕ)	...	S. 25·45	S. 14·41	S. 5·90	N. 7·64	N. 12·62	N. 25·12	N. 34·42					
Dec. 1	0 00	280	good, improving	″ 115	− 8·220	− 5·800‡	−2·790	+1·560	+ 3·380	+ 7·030	...	″ 38·93	″ 39·28	″ +0·35	″ 35·621	″ −0·324
7	0·00	205	,,	297	− 8·290	− 4·626	−2·431	+1·717	+ 3·910	+ 8·279	...	38·45	38·51	−0·06	35·888	−0·057

* In dark area. † Detached streak. ‡ Near dark area.

Date. 1903.	Approx. G.M.T.	Power.	Definition.	Approx. Longitude (System II.).	Distance from Centre at Mean Distance 5·20. Centre S. Tropical Belt (D).	S. Edge of S. Equatorial Belt (*Fs*).	N. Edge of S. Equatorial Belt (*Fn*).	S. Edge of N. Equatorial Belt (*Ls*).	N. Edge of N. Equatorial Belt (*Ln*).	Centre. N. Tropical Belt (MM)	Centre. N. Temperate Belt (N).	Polar Diameter. Observed (O).	Calculated (C).	O–C.	Reduced to Distance 5·20.	O–C.
Dec. 19	0·05	205	good, improving	° 302	− ″8·822	− ″4·932	−″2·384	+″2·063	+″3·751	+″8·308	+″12·228?	″37·08	″37·07	+″0·01	″35·954	+″0·009
		Means			− 8·444	− 5·119	−2·535	+1·780	+3·680	+7·872	+12·228?			Mean ...	35·821	−0·124
December Obs. (micrometer).		Apparent latitude ...			° S. 28·03	° S. 16·55	° S. 8·12	° N. 5·68	° N. 11·82	° N. 25·97	° N. 43·00					
		Correction to centre (B)			+1·61	+1·61	+1·61	+1·61	+1·61	+1·61	+1·61			Mean of both ...	36·091	+0·146
		True latitude (ϕ) ...			S. 26·42	S. 14·94	S. 6·51	N. 7·29	N. 13·43	N. 27·58	N. 44·61					

Date. 1903.	Approx. G.M.T.	Power.	Definition.	Approx. Longitude (System II.).	Centre S. Tropical Belt (D).	S. Edge of S. Equatorial Belt (*Fs*).	N. Edge of S. Equatorial Belt (*Fn*).	S. Edge of N. Equatorial Belt (*Ls*).	N. Edge of N. Equatorial Belt (*Ln*).	Centre. N. Tropical Belt (MM)	Centre. N. Temperate Belt (N).	N. Edge of S. Polar Region (AA).	Centre of S. Temp. Belt (B).	S. Edge N. Polar Region (Q).
Oct. 19	2·05	270 (eye estimate)	sharp	° 200	− ″9·113	...	...	...	...	+ ″7·702	+″10·810	−″13·520	−″12·567	+″13·397
October (eye estimate.)		Apparent latitude ...			° S. 29·65	...	...	...	...	° N. 25·37	° N. 36·93	° S. 48·68	° S. 44·07	° N. 48·24
		Correction to centre (B)			+ 1·77	...	...	...	...	+ 1·77	+ 1·77	+ 1·77	+ 1·77	+ 1·77
		True latitude (ϕ) ...			S. 27·88	...	...	...	...	N. 27·14	N. 38·70	S. 46·91	S. 42·30	N. 49·99
		Adopted Mean latitude ...			S. 25·93	° S. 14·67	° S. 6·20	° N. 7·46	° N. 13·02	N. 26·61	...	S. 47·0	S. 42·3	N. 50·0

Trincomali, Ceylon:
1905 *April* 10.

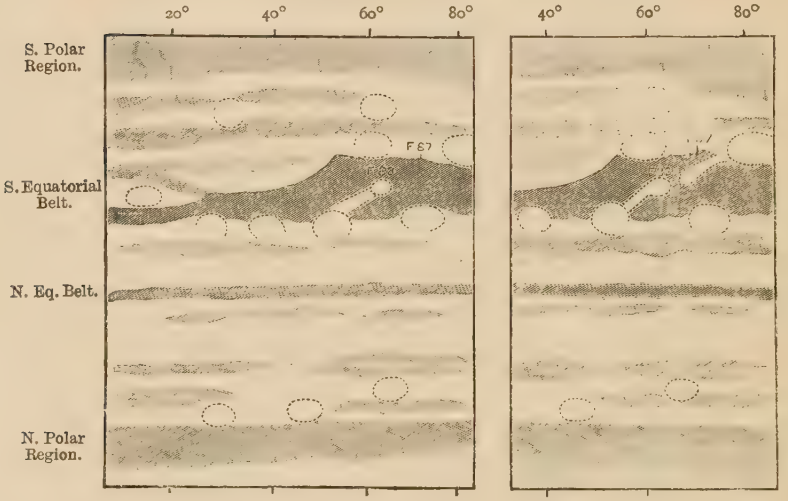
A Suspected Instance of Sudden Change on Jupiter.
By Major P. B. Molesworth, R.E.

A most curious and unique observation was made here 1903 December 17.

I quote from the observing notes :—

"The dark spot F87 (in the S. edge of S. equatorial belt) crossed the C.M. under almost perfect definition at $7^h\ 10^m{\cdot}5$ L.T. ($1^h\ 45^m{\cdot}5$ G.M.T.). The surroundings were carefully entered on the sketch (No. 128) and the neighbourhood presented the appearance shown there.

"At $7^h\ 25^m$ L.T. (2^h G.M.T.) I suddenly noticed a minute bright white spot, like i just after ingress, on the S. edge of the S. equatorial belt immediately preceding F87. I thought it very strange that I should have omitted to take the transit of such a prominent spot or to show any indication of it on the sketch. At $7^h\ 28^m$ L.T. ($2^h\ 03^m$ G.M.T.) it was



No. 128.—Longitude (System ii.). About 1·45 G.M.T.

No. 128 a.—Longitude (System ii.). About 2·05 G.M.T.

very evident, and could not have escaped the most casual scrutiny. Between 7^h25^m and 7^h30^m L.T. (2^h—2^h05^m G.M.T.) its visibility fluctuated a good deal. This was not due to any fault in the definition, which was very sharp the whole time. By $7^h\ 30^m$ L.T. ($2^h\ 05^m$ G.M.T.) the bright spot had extended as a short bright rift for some distance into the belt, its north preceding end being only separated by a

narrow streak from F83. This appearance was preserved unchanged as far as I could see till $7^h\ 50^m$ L.T. ($2^h\ 25^m$ G.M.T.), but the region was then so far from the C.M. as to make observation difficult. When the bright spot was first noticed, it was just *preceding*, and in contact with, F87 ; but the oblique rift later on appeared to enter the belt from a point immediately *following* F87.

"I am certain that there was no illusion in the question, and that the phenomenon was a case of actual rapid change on the surface of *Jupiter*. I have tried to represent the general appearance after the formation of the spot at $7^h\ 30^m$ L.T. ($2^h\ 5^m$ G.M.T.) in No. 128a, and the change can be easily seen by comparison with No. 128, which shows the same neighbourhood at about $7^h\ 10^m$ L.T. ($1^h\ 45^m$ G.M.T.)."

The telescope used was the $12\frac{3}{4}$ Calver reflector with a Steinheil monocentric eyepiece magnifying 270.

During a fairly large experience of work on *Jupiter* I have never seen anything in the remotest degree like the appearance recorded in this observation, and I am perfectly certain that there was no illusion.

The apparent change of position of the white spot with regard to the dark spot F87 is, I think, attributable to an actual motion of the white material diagonally across the belt ; forcing back the dark edge of the belt in its onward progress, and curling it over so as to form a second and darker inflection of the S. edge of the belt just following F87, which was mistaken for F87, somewhat as shown in the three diagrammatic sketches (figs. 1 to 3). In these the arrow shows the direction of motion of the white material under this supposition. I have purposely exaggerated the size of the second inflection.

Fig. 1. About $2^h\ 00^m$.

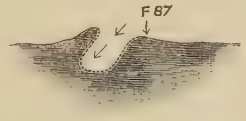


Fig. 2. About $2^h\ 03^m$.

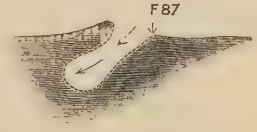


Fig. 3. $2^h\ 05^m$ and later.

It will be noticed that the outburst took place a short distance following the Red Spot bay in a latitude where rifts of this sort are practically unknown. I cannot recollect ever having seen a rift connecting the S. tropical zone with the central rift of the S. equatorial belt, but connections between the central rift and the S. edge of equatorial zone are very common. The outburst is therefore peculiar from its position as well as on account of its suddenness.

The same region was visible in twilight on 1903 December 20, but no signs of the formation could then be seen, nor was

anything remarkable noticed in its position at any subsequent date. Its existence seems therefore to have been a very short one.

Of the two sketches forwarded, No. 128 is a portion of the ordinary eyepiece chart for the night's work. No. 128a is a copy of the sketch made after the appearance of the spot in the observing note-book, the neighbourhood being filled in from No. 128.

Trincomali, Ceylon:
1905 *April* 12.

Further Note on the Density and Prolateness of close Binary Stars. By Alex. W. Roberts, D.Sc.

In vol. lxiii. (p. 527) of the *Monthly Notices* I considered the problem of determining the orbital elements of a close binary system from the light-changes produced by the mutual eclipse of the component stars as they circled round one another.

It is indeed only from photometric observations that we may hope to determine what many would regard as two of the most important facts in cosmic physics, the density of structure and the prolateness of figure of two masses of matter revolving almost, or actually in contact, round their common centre of gravity.

Fortunately the difficulty of the problem, at least when considered generally, is not in any way a serious one. The problem consists, in its simplest form, in determining the area of the projected surface of two contiguous revolving masses. The light-changes of a close binary system are of course dependent on this ever-changing area. Given, therefore, a very accurately determined light-curve, we may readily ascertain the area included within the projected outline of the system; and this being known, it is but another step to the determination of the orbital elements, of figure, of position, of movement, which govern the form of the projected area.

This of course is only a general statement of the problem. A rigorous consideration of it is a more involved matter. We may indicate one or two of the difficulties that arise.

If the orbit of a close binary system be at all eccentric, and the density small, as is usually the case with stars of this class, then there will be a constant change of figure as the mutual attraction varies in intensity. To give a concrete example, the major axis of β *Lyræ* varies in length every revolution, through at least one million miles, and this contraction and expansion along the major axis, and commensurate expansion and contraction along the two axes at right angles to it, is a continuous movement. Further, the turning points of this oscillation do not coincide with the apsidal line, but are modified by the density

and rigidity of the system, that is, by its power to adapt itself readily to the ever-changing forces acting upon it.

Then again this constant change of figure of such systems as are eccentric in orbit must produce a constant alteration in the surface pressure of the system, and this variation will naturally display itself in minute yet measurable light-changes.

These subordinate fluctuations of figure, pressure, light, and heat, are represented in every carefully determined light or motion curve. They appear as some of the contradictions and aberrations which either the spectroscope or the photometer reveals to us with regard to such stars as *β Lyræ, V Puppis*, and *RR Centauri*.

And in this connection I would strongly urge a constant watch being kept on stars of this class, for while the *mean* light-curve of a close binary star remains unchanged, each group of observations yields departures from this mean curve that are significant and important.

Every observer who has made extensive photometric observations of any single Algol binary star knows how dissimilar in points of detail, yet similar in their general family type, are the various curves obtained by grouping observations in sets. To give again a concrete example, let the light-curves of *β Lyræ* as determined by Goodrick (*De stella β Lyræ variabile*, p. 22); by Argelander (*De stella β Lyræ variabile*, commentatio altera, p. 28); by Schur (*Ast. Nac.* No. 3283); by Markwick (*Memoirs British Astron. Assoc.* vol. xi., pt. 4) be compared and the want of complete correspondence between the light-curves of *β Lyræ* taken at wide intervals of time will be at once evident.

Yet this lack of agreement is a much more significant fact in stellar physics than any apparent and unreal agreement would be. The want of complete correspondence between the curves indicated above (of *β Lyræ*) is due to, and is therefore a measure of, the changes produced (1) by the steady recession from one another of the component stars forming *β Lyræ*; (2) by the revolution of the apsides of the system.

The former needs no proof, merely a presentment of the fact, as the regular but ever-diminishing increase of period of *β Lyræ* is one of the firmly established facts of astronomy; while the second—the revolution of the apsidal line of *β Lyræ*—is made evident by a critical examination of the various light-curves.

Yet while the deeper problems that gather round these remarkable stars can only be dealt with fully when we have a long and continuous series of observations to work upon, some of the more salient points of figure and density are readily deducible from a single light-curve, obtained even from a few but well-placed observations.

I think it will be admitted that two outstanding facts of figure and density are (1) that there is a certain definite correspondence between prolateness and distance, and (2) that the density of all close binary stars is small.

Every addition to the number of close binary stars confirms these two conclusions.

The last star added to the list, *V Vulpeculæ*, also raises two points of extreme interest in any investigation dealing with stellar evolution ; and since these two matters can be satisfactorily considered from a single determination of the light-curve of the star, I think the present not unfavourable for an inquiry into their meaning and force.

The light-curve that we use as *datum* for our conclusions was deduced by Mr. Stanley Williams from observations made by himself.

The light-curve, and certain interesting matter concerning it, finds a place in the *Journ. British Astron. Assoc.* vol. xv. p. 200.

The light-curve yields the following elements of variation of *V Vulpeculæ :*

Period	75·3 Days
Mag. at max.	8·21
Mag. at prin. min.	9·65
Mag. at sec. min.	8·66
Duration of prin. eclipse...	22 Days
Duration of sec. eclipse	18 „
Duration of non-eclipse period	35 „

We use the term "non-eclipse" period instead of "constant" period for a reason that will appear later on.

In order that the proof of the prolateness of the two stars that go to make up the binary system *V Vulpeculæ* may be as convincing as possible, let it be assumed that they are spheres.

From the conditions of the problem, it is evident that during the period of non-eclipse we see both stars ; that is, 8·21 mag. represents the combined light of both components, V_1 and V_2. Let this quantity of light be regarded as equal to unity.

During principal minimum V_2 eclipses V_1, causing a decrease in brightness of 1·44 mag. ; that is, the light falls from unity to 0·26.

At the secondary minimum, V_1 eclipses V_2, causing a decrease of 0·45 mag., or a fall from unity to 0·66.

We have accordingly the following relations :

$$L_1 + L_2 = 1{\cdot}00$$
$$L_1 + mL_2 = 0{\cdot}66$$
$$L_2 + nL_1 = 0{\cdot}26$$

where L_1 and L_2 represent the light of the components V_1 and V_2, and m and n are positive proper fractions, or zero. They represent the uneclipsed portions of V_2 and V_1.

From the above equations there results the identity

$$m = \frac{8+66n}{100n-26}$$

It is evident that any fractional values of n make m greater than unity or a negative quantity—an impossible condition.

The two stars, therefore, which compose *V Vulpeculæ* cannot be spherical.

This conclusion is further borne out by the bow-shaped form of the curve during non-eclipse period. If the component stars were spheres the light-curve during the time of non-eclipse would be a *straight line.* The arched form, however, indicates a changing projected surface, such as that of a prolate spheroid revolving round its minor axis.

We now proceed to deal with the amount of this prolateness.

The equations that connect light-variation with the orbital elements of a close binary system are given in *Monthly Notices*, vol. lxiii. pp. 532–534, and so need not be stated again.

Put briefly the relations are, in the case of *V Vulpeculæ* :

$$1{\cdot}00 = L_1 + L_2$$
$$0{\cdot}66 = L_1 \sqrt{1-\cos^2 \iota\varepsilon^2}$$
$$0{\cdot}26 = L_2 \sqrt{1-\cos^2 \iota\varepsilon^2}$$

Regarding now the eclipse as a central one, that is, $\cos^2 \iota = 1$, there result the following values :

$$L_1 = 0{\cdot}72$$
$$L_2 = 0{\cdot}28$$
$$\varepsilon = 0{\cdot}39$$

The quantity ε is the eccentricity or prolateness of the figure of the component stars of the system ; that is, *V Vulpeculæ* is composed of two nearly equal masses, one of which is two and a half times brighter than the other.

The prolateness or eccentricity of figure is 0·39.

The duration of eclipse when compared with the full period of revolution yields the relative size of the component stars.

Without going into the numerical operations we find that, taking the radius of the orbit of the system as unity, the major radius of either star is 0·38 ; that is, the gap between the stars forming the system of *V Vulpeculæ* is only 0·24 in width, the radius of the orbit being unity.

These results when related to similar determinations already obtained are, we venture to think, of some importance in the study of the evolution of binary systems.

In *Monthly Notices*, vol. lxiii. p. 527, I carried out a rigorous determination of the figure and density of the close binary star *RR Centauri*, finding for this system a prolateness of 0·78 and a

distance between the components of −0·01, that is, they were still in contact.

In the *Astrophysical Journal*, vol. vii. p. 1, Mr. Myers deals with the binary system *β Lyræ*, finding a prolateness of 0·56, and that the stars had just separated.

During the past four months I have had under consideration, on the lines of the present investigation, the variation of *β Lyræ*. I find from a discussion of all available observations a mean eccentricity of figure equal to 0·58, and a mean distance (for 1850) equal to 0·01.

Placing these results in tabulated sequence we have :

System.	Distance between Components.	Prolateness according to	
		Observation.	Theory.
RR Centauri	−0·01	0·78	0·66
β Lyræ	+0·01	0·57	0·58
V Vulpeculæ	+0·24	0·37	0·35

The conclusion here is evident and unmistakable. *The nearer the components are to one another the greater their prolateness, and the amount of prolateness is in fair conformity with what theory alone would indicate.*

The density of *V Vulpeculæ* raises another and perhaps more important issue.

Without going into the numerical operations involved in arriving at the result, it may be stated that the density of the two stars which compose this remarkable binary system cannot be higher than 0·00001.

As is well known Mr. Myers found for the system *β Lyræ* a density of 0·0006.

The question arises at once : Is it possible for bodies so tenuous to hold together as they sweep round one another in rapid revolution ? The question is a legitimate one, but it is beyond the scope of the present paper to deal with it.

My object rather has been to bring forward the variation of *V Vulpeculæ* as proof of a certain definite law of prolateness in close binary systems, and also as proof that such stars are composed of matter of extreme rarity of structure.

New Double Stars. By the Rev. T. E. Espin, M.A.

The following list contains all the new pairs detected since the end of 1902. A large number of them were found during the autumn of 1904 and the spring of the present year, and consequently were too late for insertion in Professor Burnham's new catalogue. In many cases these pairs are too difficult to measure properly with the means at my disposal. Four wide

pairs have been included, as they are not found in any catalogue so far as I am aware ; but as they are all marked as double in Argelander they have not been numbered.

No.	B.D.	R.A. 1880 h m	Decl. ° ′	P. °	D. ″	Mags.	Nights.	Date.	
151	+39·12	0 2·5	+39 58	196·0	6·4	8·6 12·8	2	04·85	
152	+39·27	7·1	39 33	102·7	7·8	8·5 12·0	3	05·02	
153	+40·42	10·2	40 37	243·1	2·5	9·5 10·5	2	04·73	
154	+53·54	16·2	53 40	191·7	10·2	8·4 9·3	3	02·91	
155	+36·173	52·8	37 7	70·4	6·2	8·7 9·6	2	05·05	
156	+53·234	1 2·5	53 59	216·5	5·2	8·6 11·8	3	03·91	
157	+40·250	6·7	40 31	*f*	10±	7·0 13·5	2	04·86	
158	+40·378	42·1	40 22	45·0	6·6	8·5 9·8	1	05·02	
159	+37·386	45·1	37 11	...	5±	8·7 14·0	1	04·76	
160	+36·355	49·0	36 40	79·8	17·9	5·2 12·5	2	04·73	
161	+37·420	49·6	37 14	243·4	3·9	9·5 10·7	3	04·77	
162	+36·369	50·6	36 10	204·1	11·1	8·7 12·5	3	04·85	
163	+36·375	50·9	36 11	15·9	5·5	9·4 9·9	3	04·85	
164	+40·475	2 10·6	40 19	...	5±	8·7 13·0	1	05·02	
165	+63·435	3 28·1	63 49	171·9	3·7	9·9 10·4	3	04·05	
166	+39·844	33·7	39 19	357±	4±	8·5 13·0	1	05·02	
167	+34·730	39·8	34 58	322·6	4·4	9·0 9·1	3	04·86	
168	+36·868	4 11·8	36 26	273·2	6·7	8·5 11·5	3	05·16	
...	+59·793	12·7	59 20	58·9	32·1	6·0 8·8	1	04·07	
169	+39·1191	5 0·6	39 20	176·5	4·5	8·3 12·0	2	05·03	
170	+34·978	7·8	34 17	23·4	12·7	8·0 10·1	2	05·16	
171	+62·756	18·5	62 35	222·9	2·3	8·7 10·5	1	04·06	
172	+39·1397	36·6	39 47	135·4	4·9	9·0 10·0	1	05·02	
173	+39·1404	37·7	39 10	N.F.	4±	8·5 12·5	1	05·03	
174	Anon.	6 27·9	36 55	108·7	3·0	9·6 9·8	2	05·10	
175	+36·1498	38·0	36 35	79·4	6·4	8·9 9·4	1	05·10	
176	+34·1451	38·3	34 26	70±	6±	8·8 12·0	1	05·15	AB
				45±	6±	12·5	1	05·15	AC
177	+37·1582	38·8	37 4	...	6±	9·5 10·5	1	05·07	BC
					70±	A = 8·5	1	05·07	AB
178	+40·1776	53·5	40 1	247·7	6·6	9·5 11·5	2	00·51	BC
				151·3	8·5	A = 9·4	2	00·51	AB
179	Anon.	7 49·0	38 2	...	4±	9·5 9·5	1	05·07	
180	+36·2033	10 1·5	36 10	349·6	9·6	9·0 11·0	1	05·25	
181	+36·2166	11 6·6	36 22	142·9	5·4	9·1 10·7	3	05·29	
...	+34·2264	44·9	33 54	273·7	45·2	6·0 8·5	2	05·34	

No.	B.D.	R.A. 1880 h m	Decl. ° ′	P. °	D. ″	Mags.		Nights.	Date.	
182	+63·1346	17 21·4	63 51	19·1	6·5	9·0	11·5	4	03·60	
183	+36·3026	18 4·7	36 41	163·0	9·8	8·7	12·0	3	04·74	
184	+32·3056	4·7	32 54	157·2	5·5	9·0	11·2	2	04·73	
185	+32·3064	6·6	32 57	296·6	5·5	8·8	9·4	4	04·76	
186	+64·1256	15·6	64 1	332·7	8·6	8·2	12·0	2	03·61	
187	+51·2372	20·9	51 35	198·7	2·7	8·6	8·7	4	03·76	
188	+58·1824	31·5	58 36	224·8	11·7	8·2	13·7	2	02·81	
189	+60·1844	42·4	60 32	103·6	4·3	9·1	11·1	1	03·88	
190	+33·3228	46·1	33 4	236·0	4·2	11·5	12·0	3	04·62	BC
				295·1	12·9	A = 9·5		2	04·61	AB
191	+61·1816	19 5·2	61 4	243·9	6·1	9·1	9·8	1	03·60	
192	+59·1979	12·7	59 33	116·3	7·4	9·0	11·6	2	03·63	
193	+59·1981	13·3	59 34	113·7	8·1	8·8	11·7	2	03·63	
194	+64·1346	20·2	64 18	216·3	4·4	8·8	9·9	3	03·68	
195	+33·3496	27·9	34 2	239·5	5·6	8·3	9·0	4	04·75	
196	+32·3467	28·5	33 3	48·7	4·5	9·0	12·0	1	04·69	
197	+64·1364	35·6	64 47	19·3	8·9	8·5	10·5	3	03·68	
198	+64·1369	37·8	64 39	313·7	2·7	8·8	9·4	3	03·68	
199	+64·1386	46·3	64 23	70·7	6·5	8·0	10·5	1	03·88	
200	+34·3791	50·7	34 15	229·0	4·5	10·0	10·0	2	04·75	
201	+59·2160	57·3	59 25	145·0	4·1	9·0	11·5	1	03·64	
202	+34·3850	57·9	34 59	180 ±	6 ±	8·7	14·0		04·83	Aa
				100·0	17·3	B = 10·5		3	04·83	AB
				110·7	5·5	*b*	13·0	2	04·86	B*b*
				162·8	12·3	C	11·5	2	04·86	AC
				134·8	23·6	D	11·8	2	04·86	AD
203	+35·3983	20 3·8	35 7	131·4	5·8	8·5	10·0	2	04·94	
204	+34·3930	9·7	35 1	238·4	11·0	8·1	12·0	2	04·66	
205	+34·3936	10·4	34 38	195·5	6·6	8·8	10·7	2	04·95	
206	+37·3949	24·3	37 47	127·1	4·1	8·9	9·3	2	04·79	
...	+57·2240	42·5	57 9	162·7	68·6	5·0	8·7	3	02·83	
207	+37·4213	21 6·4	37 51	244·3	2·5	9·5	9·6	1	04·95	
208	+36·4469	8·5	37 4	143·0	3·7	8·8	10·7	2	04·82	
209	+52·2883	8·7	52 48	...	4 ±	9·0	12·0	1	03·69	
210	+32·4270	44·5	32 47	111·4	6·5	9·2	10·5	2	04·82	
211	+39·4683	45·6	39 11	196·9	2·6	9·5	10·5	1	04·77	
212	+64·1608	53·0	65 5	Double	...	9·0	...	1	03·60	
213	+63·1814	22 5·8	63 31	...	4 ±	9	11	1	03·60	
214	+34·4634	10·1	34 11	170·4	3·5	9·0	12·0	1	04·69	

No.	B.D.	R.A. 1880	Decl.	P.	D.	Mags.	Nights.	Date.
	°	h m	° ′	°	″			
215	+34·4635	10·2	34 18	141·7	8·8	8·8 12·5	1	04·69
216	+35·4850	32·3	36 4	...	4±	11 13	1	04·78 BC
				38·0	44·3	A = 8·3	1	04·78 AB
217	+36·4925	40·0	36 17	...	3±	10 11	1	04·78 BC
					70±	A = 8·7	1	04·78 AB
...	+35·4917	50·1	35 43	243·0	49·6	5·0 8·5	2	04·77
218	...	51·9	64 9	330·5	2·8	11·0 12·0	1	02·73 BC
				296·4	19·1	A = 10	1	02·73 AB (h 1833)
219	+35·5001	23 12·8	35 42	309·8	6·1	9·8 10·2	3	04·96
220	+61·2430	15·6	61 45	...	4·0	11·5 12·5	1	04·02 BC
					30±	A = 8·0	1	04·02 AB
221	+35·5153	54·7	36 7	233·9	14·8	8·1 8·8	3	04·87

Notes.

163. Measures discordant.
165. Discordant angles.
168. Discordant angles.
174. 42″ N. 10 sec p B.D. + 36°·1528.
175. h 5284 is south.
182. According to the list of proper motions in the Harvard section of the Catalogue of the Astron. Gesell., this star has a P.M. in Decl of +0″·103. If B was stationary the distance between the stars would have been 0″·9 at the time of the Harvard observation.
184. Discordant angles.
197. Discordant angles.
202. October 8, A*a* too faint to measure, another still further in the same direction. November 12, glimpsed A*a* and thought it the first of three in a line. November 14, A*a* seen—not sure that there is not a nearer and still fainter one.
204. Discordant distances.
205. Discordant angles.
207. Faint and unsteady poor measures.
212. No particulars, simple entered as double.
213. The fainter star of a wide pair.
219. Discordant angles.

Additional Note.—Since the above paper was presented Professor Hussey's ninth catalogue of new double stars has been received, and No. 195 was found to be identical with Hussey 946 :—

195. 8·0 and 10·0. 240°·8 − 5″·25. 1904·47. Hussey. 2.

On the Determination of Proper Motions without Reference to Meridian Places. By Arthur R. Hinks, M.A.

The purpose of this note is to suggest that the application of photography to the determination of the proper motion of stars leads naturally to an inversion of our ideas in respect of the origin to which these proper motions should be referred. The

suggestion is briefly this, that instead of working backwards from what we may for the moment call the foreground of brighter, and on the average nearer and faster-moving stars which are comprehended in the fundamental catalogues, we may, by the application of photography, work forwards from what we will call for the time being the background of most distant, almost stationary, and on the average fainter stars.

The determination of proper motions from meridian observations involves several difficulties of a systematic kind which may be briefly enumerated thus.

1. The systematic corrections from one catalogue to another, even when both are referred to the same fundamental system, and the systematic reductions from one fundamental system to another, are well-known troubles which embarrass every investigator of proper motion, and need no further comment.

2. Personal equation depending on magnitude, which seems to affect with the same sign, though to different degrees, all visual determinations of right ascension, becomes troublesome immediately one attempts to determine the proper motions of stars fainter than the 9th magnitude, near the limit of visual observation; and it introduces into the R.A.'s of all faint stars determined by photography a systematic error depending upon the mean magnitude of the stars adopted as standard. All attempts to determine the value of this visual magnitude equation experimentally, or to eliminate it by process of observation, seem to be unsuccessful. Take as an example the case of the *Repère* stars for the reduction of the *Eros* observations. They were observed at a great number of places. They have been discussed very thoroughly by Professor Tucker, and formed into two normal systems (Paris *Eros* Circular, No. 11). On the strength of determinations of the magnitude equation in the places from Lick and Königsberg, the first by the method of screens, the second by the clockwork transit micrometer, Professor Tucker concludes that his first normal list is free from magnitude equation (*L. O. Bulletin*, No. 72). Yet I find on comparing his list with the photographic places of the stars from six observatories (Bordeaux, Catania, Northfield, Paris, San Fernando, and Toulouse), which have no appreciable photographic magnitude equation relative to one another, that between Tucker's List I. and the mean of these six observatories there is a magnitude equation of about $0^s.02$ per magnitude. I conclude that it is by no means certain that Tucker's System I. is really free from magnitude equation, and that visual and photographic determinations of R.A. cannot at present be brought into accord in this particular.

3. Still more serious is the probability that the constant of precession, necessarily determined from a limited selection of the brighter stars, will be found not applicable to the stars in general, or to other selections. It has been shown by Professor

Kapteyn in his address delivered at the St. Louis Congress,* and also by Messrs. Dyson and Thackeray in their discussion of the proper motion of Groombridge stars (*Monthly Notices*, 1905 March), that the distribution of proper motions is so far from being random that existing determinations of the solar apex are more or less invalidated. But determinations of the solar apex and the precession constant are essentially entangled; if bright stars give a different position of the apex from faint ones, it is more than probable that they will give different values of the precession constant also. At any rate, a first criterion for the choice of stars from which to determine the precession constant is that these motions shall not be systematic over considerable areas of the sky, and it is now certain that the stars which have been actually used do not satisfy that criterion. We can hardly avoid the conclusion that our knowledge of the precession constant is not sure enough to allow us to pass with confidence from the bright stars down the whole range of magnitudes which are within the scope of the photographic method.

Can we then say that our present system of meridian places of bright stars is a sure foundation on which to base the proper motions of faint stars determined by photography? Evidently not; the persistence of magnitude equation in spite of all efforts and the want of homogeneity in the system of the meridian stars forbid it. The former difficulty may be overcome; the latter must prevail so long as star-places are referred to shifting planes of reference whose motion might be adjusted to one homogeneous system of stars observable with meridian circles, but becomes indeterminate if not undefinable when more than one system is involved in the limited number of available stars.

So far as I am aware, the suggestion has not been made hitherto that by the use of photographic methods one may dispense altogether with any reference (except a quite subsidiary one) to these shifting planes, and determine the proper motions of the stars independently of the precession constant. The proposition is evidently true if one admits the possibility of picking out to serve as a background a set of stars so distant that their peculiar proper motions are very small and their parallactic motion infinitesimal. Professor Newcomb gives reasons for believing that the stars extend in every direction beyond a sphere whose radius corresponds to a parallax of 0″·001. The parallactic motion of stars on that sphere would not exceed 0″·4 per century (using Campbell's determination of the solar motion). And since the sphere of *lucid* stars probably extends to half that distance, we might hope to get a background not unreasonably faint.

Now it appears to me that the selection of stars for the back-

* This address has not yet been published. The result that there are two distinct streams of stars has been quoted by Professor Turner (*Observatory*, 1905 February, p. 118). By the great kindness of Professor Kapteyn I have had the privilege of reading a portion of the address in manuscript.

ground becomes a relatively simple matter provided that star-photographs are treated in the simplest possible way. Imagine that we possess for a given epoch a set of photographs on the same centre : exposures, let us say, with an astrographic telescope, of one minute, giving measurable images of stars between 6^m and 10^m ; of three minutes for stars between 8^m and 11^m ; perhaps of thirty minutes for stars between 10^m and 13^m. Exposures beyond thirty minutes will not be good for measurement over a large field owing to refractional distortion. So let us suppose the series continued with an instrument like the Bruce telescope down to 15^m ; and for a small central field with a large reflector down even to 17^m. If rectangular coordinates are measured on all these plates they can be reduced in the simplest fashion one to another, so that in the end we have a system of rectangular coordinates homogeneous (except for instrumental causes) for all the stars in the field—a system, be it noted, whose orientation and scale-value need not be known to any refinement, while it may even involve refraction and aberration, provided that the corrections for all these errors, were they to be applied, would be expressible as linear functions of the coordinates.

Imagine, further, a similar system of rectangular coordinates of the same stars on the same centre (with respect to the stars) made after a lapse of years ; and suppose one system reduced to the other *en bloc* by the ordinary linear reduction. The residuals for each star would represent its proper motion relative to the mean of the rest. All stars with sensible proper motions might then be excluded, and a new reduction made with the remainder. The proper motions of the faster-moving stars with respect to this residuum would not indeed be absolute, since they would not include the average parallactic motion of the residuum during the interval between the two epochs. But they would more nearly represent the absolute proper motions than any which could be derived by reducing the measures to R.A. and declination through the introduction of "standard" stars. It is unnecessary to follow out in words the way in which this procedure would work. But it is evident that as the process was repeated and extended there would be a straightforward sifting out of foreground stars ; a continual approximation to a motionless background ; and an easy way of forming an estimate from time to time of the amount of parallactic motion still in the background by classifying residuals according to magnitude.

The process would be carried on in regions all over the sky, and it would be necessary to select some system of axes to which the motions might be referred. Here, and here only, should we require to know the coordinates of a few stars determined by meridian instruments. But having neglected the existence of the equator and the vernal equinox up to this point, we must not fall from old habit into the mistake of referring the proper motions now to these discarded origins. It would be just as simple and

clearly more advantageous to refer everything to an assumed galactic plane.

We may anticipate the objection that the method is illusory, since it may be true that there is no motionless background; that there may be no observable stars so far off that their parallactic motion is insensible; and that in any case there can be no certainty about a method that does not tie the various regions together and prove that they are relatively motionless. The objection does not appear to me to be sound, since we determine by the photographic method the proper motions of all the meridian stars which are not too bright, and their places with respect to the rest; so that we have at our disposal the whole results of meridian observation to establish the relative fixity of our different patches of background. Yet this harking back to meridian places is not by any means equivalent to an ultimate return to the method which we proposed to abandon. It is essentially different from it in three respects: we use the meridian observations only to give us the absolute distances apart of stars upon the sphere, which can be obtained practically free from any precessional effects; the proper motions of these stars also, the stars observed on the meridian, are determined, not from the meridian observations, but by the photographic method; and the whole determination of proper motion is carried as far as the final step without any reference whatever to the meridian, so that it cannot get entangled with any of the difficulties that beset meridian observation.

A word may be said as to the choice of regions for the application of this proposed method of taking samples of proper motions. It would be a mistake to start *de novo* with a scheme of centres arranged with perfect symmetry after a cut-and-dried plan, because in so doing we should inevitably miss all the things that are of particular interest. On the contrary, one might let the regions to a great extent select themselves. Some of the most interesting regions of the sky were photographed twenty years ago; we should gain twenty years if those photographs could be measured, and an attempt must be made to do so. And there are a dozen other reasons for selecting particular fields—the presence of a group of Wolf-Rayet stars, or of stellar gaseous nebulæ, or of a star cluster which has already been surveyed. The region round a variable star whose photometric magnitudes are well determined would be interesting; so would a nebula like *Messier* 33, whose condensations are so nearly stellar that some of them might be measured; and one or two binaries whose real orbits may be large enough to measure; and some of the regions containing the fainter helium stars; and the fields of those Novæ which survive as faint stars after passing through the planetary nebular stage. When all these obviously interesting things had been provided for, it would probably be found that their distribution was not as symmetrical as might be desired about the galactic plane; but the gaps could be filled in on

Astrographic Catalogue centres. The scheme is in fact potentially in operation, for the astrographic plates have many of them been measured and published in rectangular coordinates, and the age of some of them is already considerable; they provide thoroughly for stars down to the 11th magnitude. The most urgent matter is to discover how good reflector photographs may be for carrying the measures down to the 15th or 16th magnitude. Perhaps I may add that we hope to be able to borrow some plates, and try this at Cambridge in the not distant future.

Cambridge Observatory:
1905 *May* 11.